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Introduction

Cooperative studies included in this report were initiated in 1989 between U.S. Department of the Interior, Bureau of Land Management Idaho State office and Department of Agriculture, Forest Service, Rocky Mountain Research Station, Shrub Science Laboratory. The principal objective of the studies was to select and develop native plants to restore disturbances principally within the arid regions occupied by big sagebrush (Atremisia tridentata), salt desert shrublands, and associated upland shrub steppe communities. In addition, studies were designed to investigate and develop species that could be used to control the spread of fires and to serve as fuel barriers on sites occupied by cheatgrass (Bromus tectorum). Studies also included investigation of methods to control cheatgrass, create suitable seedbeds and seeding of selected native species. Primary emphasis has been given to the development native grasses adapted to the Snake River Plain and shrub steppe communities in central Utah. Studies include evaluation of ecotypic populations, areas of distribution and features of individual populations that contribute to their ecological adaptation. Efforts to advance individual species for use in revegetation efforts have required investigation of germination characteristics, phenological and morphological traits, and development of agronomic practices to maximize establishment potential. Plant growth rates, measured by respiration and heat loss, have been used to assist in the identification and verification of different ecotypes within selected species. These techniques have proven useful in evaluation of adaptive characteristics among different populations and certainly speed up the plant selection process.

Most native species required for community restoration have not been grown under cultivation. Seed production from wildland stands is not sufficient to supply current demands, consequently, seed must be produced under cultivation to provide a consistent supply. In addition, between four and six native "source identified" selected class releases from current studies; these also require some evaluation of seed culture practices to provide an understanding of field growing requirements. Studies have been developed to investigate the effects of different field rearing and harvesting practices on seed production, seed quality, and seed germination features. Some studies were conducted to determine if seed rearing conditions could be used to improve seedling vigor and establishment traits.

A number of separate studies have been conducted to investigate methods and techniques for seeding sites occupied by annual weeds. Studies included various chaining and harrowing procedures for use on steep slopes where creation of suitable seedbeds is essential. Planting seeds at different rates and row spacings have also been evaluated , as well as seeding individual native species as a means to control weed invasion and facilitate the recovery of native species. Most recently, studies have been conducted to evaluate the use of "Oust" herbicide to control cheatgrass, medusahead and other annual weeds. Studies include investigation of rates and timing of application, persistence of the herbicide in the soil, and affects on associated species.

Testing and development of species that can serve as fuel barriers and are adapted to the arid shrub communities of the Intermountain region has required a reassessment of plants and planting schemes. Attention has been directed to the selection of species that are adapted to the southern Idaho region, are sufficiently competitive to displace or control cheatgrass, and posses low flammability and burning features. Development of burning trials to evaluate the features of individual species and the flammability index of established stands has required additional technology. Studies have resulted in the development of a few native and introduced species that can be successfully used to serve as greenstrip plantings. These species have been advanced into commercial production.

The primary objectives of these studies has been to advance restoration of native communities. This work has resulted in the selection and development of a number of native species and will permit their use in large scale restoration projects. Future studies should include further seed production trials and examination of methods for controlling weeds. Currently technology and plant materials are available to initiate a series of restoration projects. Studies should be designed to examine the competition relationships among native species that influence the reestablishment of entire communities. The influence of site conditions and weed control measures on initial establishment should be a primary objective. In addition, examination of secondary successional processes is required to determine impacts of seeded species and their effects upon natural recovery processes.

Comparing 53 Native Collections of Bluebunch Wheatgrass and Snake River Wheatgrass in Two Common Garden Experiments at Nephi, Utah and Orchard, Idaho

Stephen B. Monsen, Darren G. Naillon, Stanley G. Kitchen

Problem

Bluebunch wheatgrass (Psuedoroegneria spicata [Pursh] A. Love) is an important native range grass of western North America. The desirable attributes of this grass include: high palatability, high forage quality, wide adaption, and reasonable drought tolerance. High palatability and limited grazing tolerance has resulted in this species general decline as a component of the shrub/steppe and sagebrush/grass communities. Grazing at the boot stage reduces vigor and competiveness for several years, and increases susceptibility to further grazing damage (Miller and others 1986). Bluebunch wheatgrass has had a reputation of poor seedling vigor often blamed for poor stand establishment in rangeland seedings. A major effort has been initiated to examine a broad range of native bluebunch wheatgrass germplasm and select suitable candidates for rangeland restoration projects in southern Idaho.

The traditional bluebunch wheatgrass taxa has recently been separated into two distinct species that are morphologically and ecologically similar. The most widespread species is bluebunch wheatgrass (Psuedoroegneria spicata [Pursh] A. Love). Ecotypes of this species vary in rhizome development, seed size, leaf blade width, and seed awn development. Recently Carlson (1986) and others have recognized Snake River wheatgrass (Elymus lanceolatus (Scribn. & Sm.) Gouldssp. wawaiensis) as a species distinct from bluebunch wheatgrass. The name Snake River wheatgrass comes from the original specimen collected in the Snake River Canyon, Whitman County, Washington. This species does not hybridize with bluebunch wheatgrass. It is not rhizomatous and is also known to be more vigorous, grazing tolerant, and easier to establish than bluebunch wheatgrass (Jones and others 1991). In native collections it is always awned whereas bluebunch can vary relevant to this attribute. Thus far all native collections of Snake River wheatgrass have come from northeast Oregon and southeast Washington.

Three named cultivars of these two species have been previously released. 'Whitmar' and 'Goldar' are two released bluebunch wheatgrass cultivars. 'Secar' was originally released as a bluebunch cultivar, but has since been recognized as Snake River wheatgrass. There is some concern about general adaptability for southern Idaho of these releases due to the fact that all were developed from southeastern Washington germplasm.

Seed from 80 populations of both species were collected or acquired from six western states for use in common garden testing. Evaluations were made to assess: initial establishment, survival across years involving severe climatic conditions, yearly shoot growth, and general vigor each year. These evaluations helped to delineate geographical populations of bluebunch wheatgrass and selections of Snake River wheatgrass occurring within the Intermountain Region and surrounding area. Comparing these varied collections in two common gardens has proven helpful.

Methods

Bluebunch wheatgrass and Snake River wheatgrass greenhouse reared seedlings were transplanted at Orchard, Idaho and Nephi, Utah in 1989 and 1990. These common garden studies were organized into random blocks of 24 plants with three replications. Plants were evaluated for height, crown and vigor in 1989, 1991, 1993, 1994 and 1995. Only a vigor rating was taken in 1990. Data have been collected to assess differences in initial establishment, yearly shoot growth, general health and survival, particularly following severe drought conditions in 1992 and 1994. Vigor represented a subjective evaluation of the plants health on a scale of one to five, five being highest. Height and crown measurements were recorded in centimeters using the maximum height and crown of the plant. Plant survival was noted as no values were entered for dead plants.

Statistical Analysis

The data of vigor, height, and crown for each year were combined to create an index value representing the overall characteristic of each plant regarding health and growth indices. The height and crown were given approximately equal weight by adding the centimeters representing each together. This number was multiplied by the vigor to give weight to the general assessment of the plants health. These index values were compared by year using analysis of variance. Means were separated using Student-Newman-Keuls (SNK) multiple range test for all main effect means. All differences reported are significant at $p<0.05$.

Results/Discussion

In comparing the index values of Snake River wheatgrass and bluebunch wheatgrass at the Nephi, UT and Orchard, ID sites to one another they were not significantly different. This allowed the two sites to be combined to compare the different sources, disregarding site. The two sites are however, very different from one another in soil type and climatic conditions. Orchard represents the dryer conditions suitable for these grasses while Nephi is more typical of areas adapted for these species. Reflecting this adult survival was significantly higher at Nephi than at Orchard(table 4).

No single collection performed best under all test conditions. Snake River wheatgrass collections generally performed best with regard to survival, vigor, height and crown assessments. Bluebunch wheatgrass collections from southeast Washington, northeast Oregon, and extreme western Idaho performed better than other collections with regard to survival, vigor, height, and crown assessments. This is a very comprehensive long term study that includes large amounts of data. Conclusions presented in the tables typify a representative selection of all the information possible. The presented information represents the best possible comparisons to draw conclusions from.

Collections of Snake River wheatgrass from Wawawai, Washington and Enterprise, Oregon have survived better, have greater seedling vigor, good seedling and establishment traits compared to other collections obtained from the Snake River Plain. These sources of Snake River wheatgrass provide better forage and vegetative growth features than does the variety ‘Secar’. Snake River wheatgrass collections performed better at Orchard than bluebunch sources . The average annual precipitation of Orchard is 8 inches. This is a dry site for bluebunch wheatgrass and Snake River wheatgrass testing well, drought tolerance for these species. Unexpectedly, juvenile survival was significantly lower at Nephi than Orchard. This can be attributed to lower quality transplants that were planted at Nephi. Drier conditions at Orchard did cause significantly more mortality in plants that survived the first two years and then died (table 4).

Bluebunch wheatgrass sources from: Baker, OR; Brownlee Dam, ID; Colton, WA; Grande Rhonde, OR; Anatone, WA and Lewiston ID performed better than all other collections in this study. Index values over all years were generally significantly higher than other tested material. All of these sources performed better than 'Secar' and 'Goldar'. Survival, vigor and biomass production exceeded other sources. This material is generally from a similar region of the Snake River Plain. Not surprisingly, characteristics of closely related material performed similarly.

Seedling establishment of bluebunch wheatgrass has been a concern in many previous plantings. In table 1 the 1989 index value for Snake River wheatgrass from Wawawai, WA was significantly higher than all other sources of Snake River wheatgrass and bluebunch wheatgrass. This source established well and produced the most biomass the first year of establishment. Regarding establishment the first year, 'Secar' and 'Goldar' had significantly lower index values than other Snake River wheatgrass and bluebunch wheatgrass collections from Baker, OR; Brownlee Dam, ID; Colton, WA; Grande Rhonde, OR; Anatone, WA and Lewiston, ID. It is possible to obtain better establishing material than is presently available.

In 1992 and 1994 drought conditions persisted at both planting sites. During the years of high stress plants performed similarly as displayed by the large SNK groupings of the index values for 1993 and 1994. During these years there was some mortality related to the dry conditions. No significant mortality can be directly correlated to the drought years.

Management Implications

Bluebunch wheatgrass and Snake River wheatgrass deserve consideration in restoring rangelands. This study has provided germplasm material that is superior to presently available sources. Restoring native bunchgrass communities is possible if seed is selected carefully and proper technique are used in planting it.

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Jones, T. A., C. C. Neilson, and J. R. Carlson. 1991. Developing a grazing-tolerant native grass for bluebunch wheatgrass sites. Rangelands 13:147-150.

Miller, R. F., J. M. Seufert, and M. R. Haferkamp. 1986. The ecology and management of bluebunch wheatgrass (Agropyron spicatum): a review. Oregon Agr. Exp. Sta. Bull. no. 669.

Technology Transfer Products

Germplasm of Anatone, WA bluebunch wheatgrass is currently in production for release as source identified material to be used in rangeland seedings. Sources from Levan, UT and Boise, ID are also planned for release. Anatone, WA germplasm has proven to have good seed production, drought tolerance, seedling establishment and survival in dry conditions. This source performed better than 'Goldar' and should be considered in restoration work. The Levan, UT material comes from Pinyon-juniper under-story in central Utah. Its release is intended for restoration following wildfire where Pinyon-juniper communities are expected to return. This source performs well in the under-story of this community. Boise material was collected in the foothills just east of Boise. The availability of germplasm that performs better than currently released varieties will give land managers better material to select from in planning restoration projects on rangelands.

Table 1. Index values for 25 collections of Snake River wheatgrass and bluebunch wheatgrass.

Source	B#	89 Index	91 Index	93 Index	94 Index	95 Index
Wawawai, WA	**79**	**101 a**	**210 a**	**579 a b**	**507 a**	**586 a b**
Baker, OR	68	82 b	155 b c d e f g	539 a b c d	532 a	601 a b
Enterprise, OR	**51**	**76 b c**	**147 b c d e f g**	**510 a b c d**	**458 a b c**	**719 a**
Brownlee Dam, ID	49	44 d e f	162 b c d e f	591 a	484 a b	600 a b
Colton, WA	83	50 d e	151 b c d e f g	558 a b c	466 a b c	611 a b
Grande Rhonde, OR	52	61 c d	133 c d e f g h i	528 a b c d	521 a	612 a b
Penawawa Cyn., OR	**82**	**83 b**	**189 a b**	**486 a b c d e**	**454 a b c**	**581 a b**
Anatone, WA	53	35 e f g	163 b c d e	520 a b c d	459 a b c	610 a b
Lewiston, ID	67	80 b	161 b c d e f	524 a b c d	434 a b c	586 a b
Colton, WA	**66**	**75 b c**	**137 c d e f g h**	**485 a b c d e**	**454 a b c**	**531 b c d**
Secar	**24**	**49 d e f**	**173 a b c d**	**474 a b c d e**	**423 a b c d**	**567 b c**
Goldar	25	26 f g	179 a b c	500 a b c d e	440 a b c	438 c d e f
Wallowa Mtns., OR	50	57 c d e	125 b c d e f g h i	427 b c d e	415 a b c d e	494 b c d
Dingle, ID	61	45 d e f	130 c d e f g h i	435 a b c d e	423 a b c d	441 c d e f
Pittsburg Landing, ID	46	43 d e f	107 g h i j	507 a b c d	359 c d e f	443 c d e f
Dayton, WA	76	51 d e	112 e f g h i j	411 c d e f	373 b c d e	485 b c d e
Lamoille Cyn., NV	43	44 d e f	91 h i j	430 b c d e	348 c d e f	469 b c d e
Riggins, ID	64	61 c d	124 d e f g h i	349 e f g h	364 c d e f	399 f g
Levan, UT	34	46 d e f	110 f g h i j	414 c d e f	323 d e f	395 f g
Evanston, WY	60	42 d e f	106 g h i j	381 d e f g	314 e f	352 f g
Arco, ID	59	43 d e f	92 h i j	412 c d e f	275 f g	312 f g
Crows Nest, ID	27	46 d e f	87 h i j	281 f g h	217 g h	329 f g
Snowville, UT	45	42 d e f	84 i j	281 f g h	305 f g	272 g
Salmon, ID	57	42 d e f	115 e f g h i	257 g h	271 f g	302 f g
Birds of Prey, ID	26	20 g	63 j	226 h	175 h	261 g

Bold print distinguishes Snake River wheatgrass collections.
Different letters are significant at $p<0.05$.

Table 2. Percent survival at Orchard of sources of bluebunch wheatgrass and Snake River wheatgrass. **Bold sources are Snake River wheatgrass**. Different letters are significant at $p<0.05$.

Source	B #	Transplant Survival	Juvenile Survival	Adult Survival	Total Survival
Wawawai, WA	**79**	**74ab**	**95ab**	**98a**	**68ab**
Baker, OR	68	56ab	98a	80a	43abcdef
Enerprise, OR	**51**	**86a**	**97a**	**97a**	**81a**
Brownlee Dam, ID	49	25ab	87ab	89a	17cdef
Colton, WA	83	56ab	64abc	84a	32bcdef
Grande Rhonde, OR	52	54ab	95ab	84a	43abcdef
Penawawa Cyn.,	**82**	**83a**	**98a**	**96a**	**79a**
Anatone, WA	53	51ab	88ab	90a	42abcdef
Lewiston, ID	67	53ab	96ab	93a	49abcdef
Colton, WA	**66**	**61ab**	**88ab**	**98a**	**54abcde**
‘Secar’	**24**	**68ab**	**88ab**	**96a**	**57abcde**
‘Goldar’	25	65ab	75abc	69a	33abcdef
Wallowa Mtns., OR	50	38ab	89ab	58a	19bcdef
Dingle, ID	61	65ab	47c	53a	22bcdef
Pittsburg Landing, ID	46	21b	96ab	68a	11def
Dayton, WA	76	64ab	98a	100a	63abc
Lamoille Cyn., NV	43	51ab	86ab	65a	27bcdef
Riggins, ID	64	56ab	82abc	59a	25bcdef
Levan, UT	34	72ab	87ab	86a	54abed
Evanston, WY	60	33ab	89ab	82a	24bcdef
Arco, ID	59	22b	54bc	78a	7f
Crows Nest, ID	27	60ab	78abc	73a	33abcdef
Snowville, UT	45	58ab	90ab	89a	43abcdef
Salmon, ID	57	49b	74abc	80a	26bcdef
Birds of Prey, ID	26	25b	72abc	56a	

Table 3. Percent survival at Nephi of bluebunch wheatgrass and Snake River wheatgrass. **Bold sources are Snake River wheatgrass.** Different letters are significant at $p<0.05$.

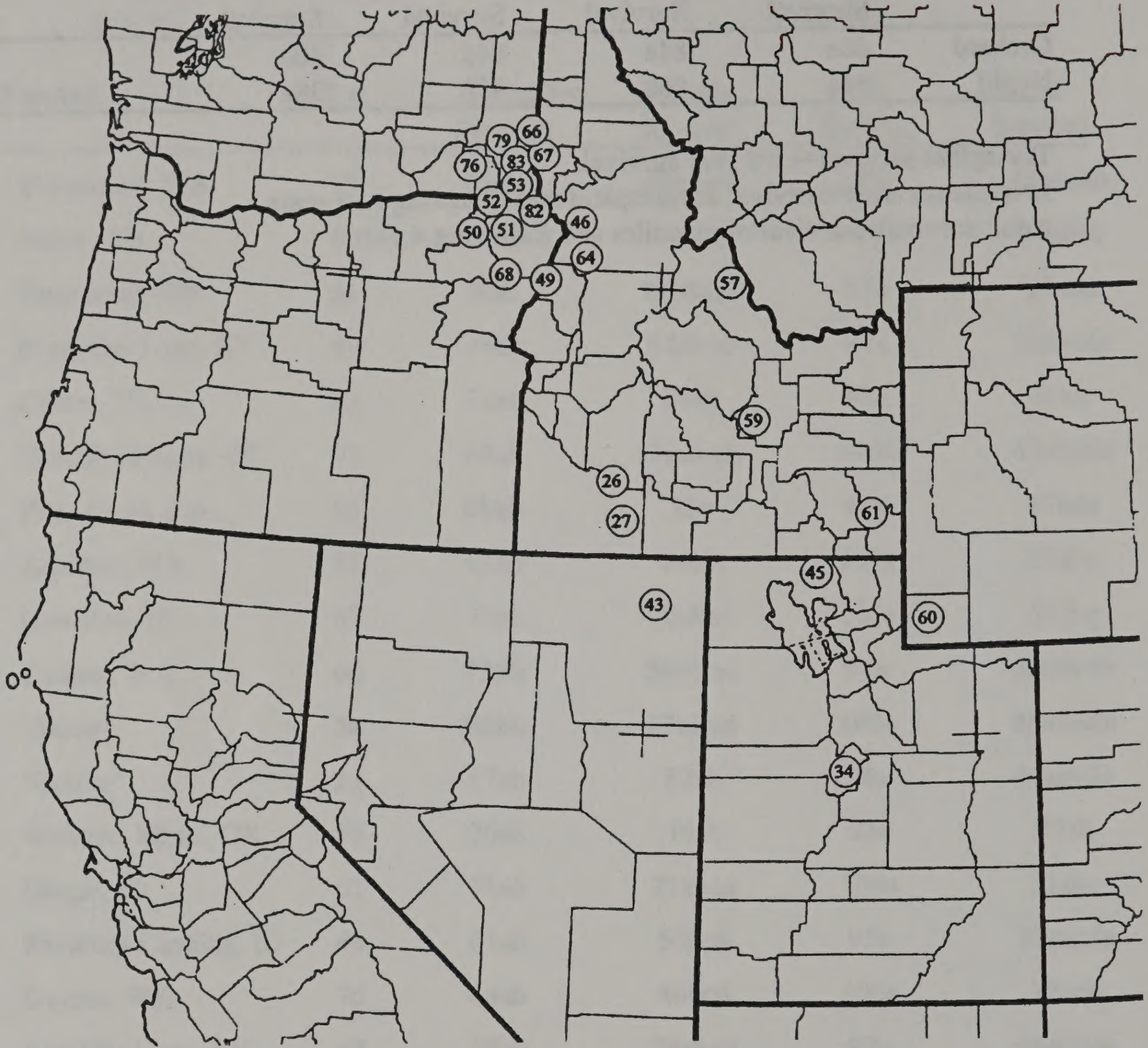
Source	B #	Transplant Survival	Juvenile Survival	Adult Survival	Total Survival
Wawawai, WA	**79**	**74ab**	**60abcd**	**100a**	**43abcde**
Baker, OR	68	64ab	78abc	100a	50abcd
Enerprise, OR	**51**	**35b**	**64abcd**	**87a**	**19cde**
Brownlee Dam, ID	49	49ab	62abcd	95a	29abcde
Colton, WA	83	71ab	88ab	98a	61ab
Grande Rhonde, OR	52	65ab	72abcd	100a	47abcde
Penawawa Cyn.,	**82**	**65ab**	**33c**	**67a**	**17cde**
Anatone, WA	53	61ab	86ab	100a	51abc
Lewiston, ID	67	75ab	70abcd	100a	53abc
Colton, WA	**66**	**75ab**	**56abcd**	**94a**	**39abcde**
'Secar'	**24**	**50ab**	**67abcd**	**100a**	**33abcde**
'Goldar'	25	57ab	82ab	96a	44abcde
Wallowa Mtns., OR	50	76ab	78ab	92a	57ab
Dingle, ID	61	71ab	71abcd	100a	51abc
Pittsburg Landing, ID	46	61ab	50bcd	95a	31abcde
Dayton, WA	76	44ab	46bcd	100a	18cde
Lamoille Cyn., NV	43	58ab	74abcd	97a	44abcde
Riggins, ID	64	53ab	54abcd	93a	28bcde
Levan, UT	34	75ab	76abc	98a	56abc
Evanston, WY	60	79a	86ab	100a	68a
Arco, ID	59	58ab	41bcd	100a	24bcde
Crows Nest, ID	27	69ab	74abcd	85a	44abcde
Snowville, UT	45	63ab	51bcd	91a	28bcde
Salmon, ID	57	8c	100a	83a	6e
Birds of Prey, ID	26	53ab	30d	89a	11de

Table 4. Percent survival of all sources at each site.

	Transplant Survival	Juvenile Survival	Adult Survival	Total Survival
Orchard	60a	84a	84a	40a
Nephi	54a	66b	95b	38a

Transplant survival=First year survival.
Juvenile survival=Survival as transplant and following two years.
Adult survival=Survival of juveniles and following 4 years.

Figure 1. Bluebunch wheatgrass collection locations



- (79) Wawawai, WA
- (68) Baker, OR
- (51) Enterprise, OR
- ㊾ Brownlee Dam, ID
- (83) Colton, WA
- (52) Grande Rhonde, OR
- (82) Penawawa Cyn., OR
- (53) Anatone, WA
- (67) Lewiston, ID
- (66) Colton, WA
- ㉔ Secar
- ㉕ Goldar
- ㊿ Wallowa Mtns., OR
- (61) Dingle, ID
- ㊻ Pittsburg Landing, ID
- (76) Dayton, WA
- ㊸ Lamoille Cyn., NV
- (64) Riggins, ID
- ㉞ Levan, UT
- (60) Evanston, WY
- (59) Arco, ID
- ㉗ Crows Nest, ID
- ㊺ Snowville, UT
- (57) Salmon, ID
- ㉖ Birds of Prey, ID

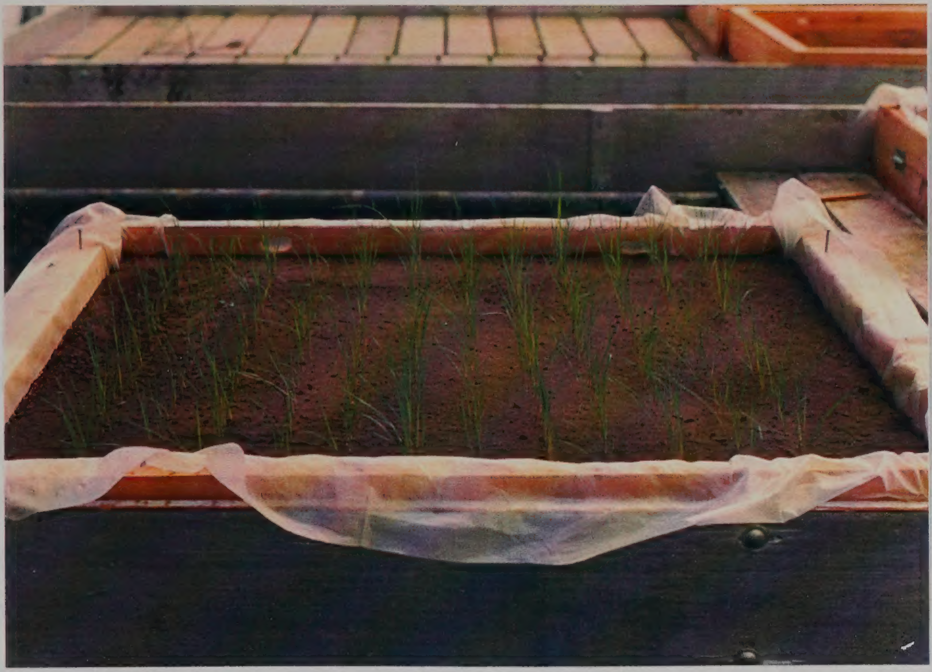


Figure 2. Seedling germination and establishment trials. Variation in plant performance can be observed.

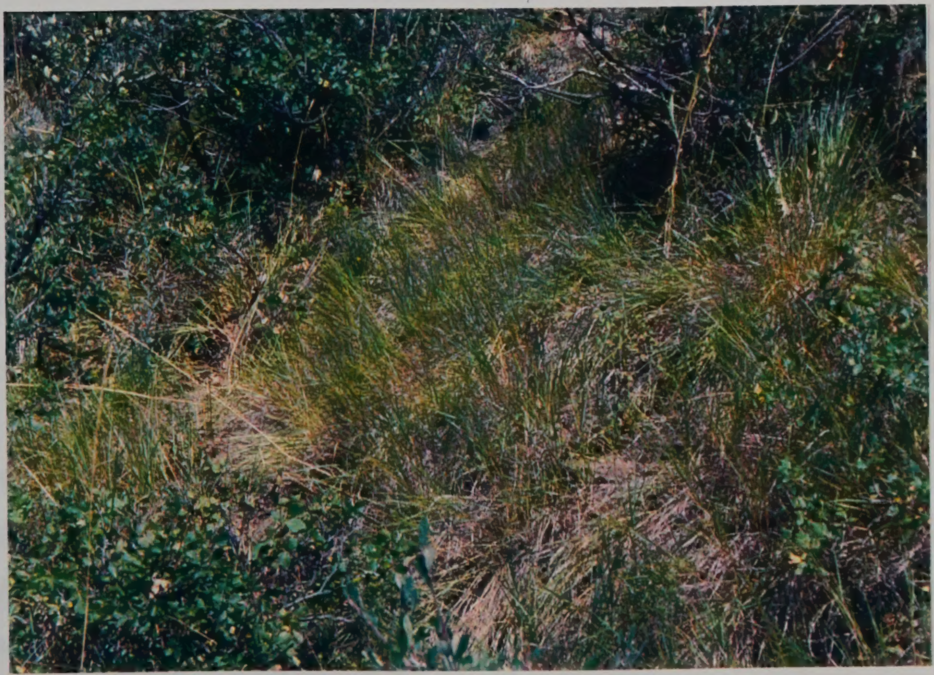


Figure 3. A rhizomatous form of bluebunch wheatgrass.

Selection for Seedling Vigor in Bluebunch Wheatgrass

Stanley G. Kitchen and Stephen B. Monsen

Introduction

Bluebunch wheatgrass (Pseudoroegneria spicata [Pursh] Love) is a dominant cool-season bunchgrass native to much of the semi-arid landscapes found in western North America. Historically, many populations have been reduced due to poor management, particularly excessive grazing practices. Stand establishment from seedings of bluebunch wheatgrass in revegetation and restoration projects has not always equaled that of introduced grasses adapted to the same sites (e.g. crested wheatgrasses). Less than satisfactory stand establishment has led to the commonly held belief that bluebunch wheatgrass has poor seedling vigor (Jones and others 1991). Although numerous stands have been attained from extensive seedings.

Objectives

In this study we evaluated variability among widely collected accessions of bluebunch wheatgrass in seed size, germination rate, seedling emergence and growth rate from depth planting, and maximum coloeptile length; attributes frequently associated with seedling vigor (McKell 1972, Asay and Johnson 1983, Berdahl and Barker 1984). We also investigated collection site-related variability within accessions and among-plant variability within a population. The primary objective was to determine opportunities, either by selection or by rearing techniques, for improving seedling vigor in bluebunch wheatgrass.

Methods

Seeds were collected from 47 naturally occurring populations of bluebunch wheatgrass in eight states. Commercial collections of the cultivars 'Goldar' bluebunch wheatgrass and 'Hycrest' crested wheatgrass were included for comparison. After cleaning, mean seed weight was determined for each collection. Replicated subsamples of each collection were germinated under controlled laboratory conditions at 15/25° and 2° C to determine near-optimum and near-freezing germination rates. Seeds were classified as germinants when both radicle and coleoptile growth had met specific criteria. Indices of germination rate were calculated using methods modified from Maguire (1962).

Greenhouse experiments were conducted to determine successful germination and emergence from a uniform planting depth of 4.0 cm. Rows of seeds (50 each) were sown in planter boxes using a randomized block design. Water was not limiting. Seedlings were counted after 28 days. Shoots were harvested, dried, and weighed to determine above-ground growth rate. Seedling emergence percentages were adjusted for total viable seeds using germination data.

We collected seeds of nine representative accessions of bluebunch wheatgrass in 1993 from nursery centers in Orchard, Idaho and Nephi and Spanish Fork, Utah. Wild parent populations were also recollected when possible. Seeds were processed and sub-lots were weighed to determine mean seed weight. Subsamples were germinated at 2° C to determine cold-temperature germination rate. Finally, coleoptile lengths for 20 germinants of each accession were measured after seeds were chilled for two weeks and incubated in the dark for eight days at 20/30° C.

In order to assess within-population variability, seeds of four accessions of bluebunch wheatgrass were collected by plant (n=6) from the Spanish Fork nursery in 1995 and 1996. Again, seed weights (96 seed only), cold-temperature germination rates, and mean maximum coleoptile lengths (60 seeds/accession/year) were determined as previously described only on a plant by plant basis.

Results and Discussion

Results of preliminary evaluations using seeds from wild populations were reported in the Journal of Range Management (Kitchen and Monsen 1994). For a thorough review of results and interpretations we refer the reader to that publication. A brief summary is presented here.

Seed weight for wild-collected seeds ranged from 176 to 437 seeds/g. Emergence percentage was equally variable ranging from 5 to 66 percent. Mean dry shoot weight of emerged seedlings varied from 1.6 to 9.5 mg/plant. Significant correlations between seed weight and emergence percentage and seed weight and dry shoot biomass were observed. Germination rate indices varied from 25.2 to 51.2 at 15/25° C and from 9.6 to 20.5 at 2°

C. Values for seed weight, emergence success, and mean dry shoot weight for 'Goldar' bluebunch wheatgrass were higher than overall means (table 1). 'Goldar' tested well in both germination rate experiments as well. One accession from Asotin County, Wa. (B-53) was superior to 'Goldar' in cold-temperature germination rate, seedling emergence success, and mean dry shoot weight.

When compared to bluebunch wheatgrass accessions, 'Hycrest' crested wheatgrass seeds germinated more rapidly, and had a faster seedling growth rate (table 1). Differences in germination rate between 'Hycrest' and bluebunch wheatgrass accessions were due to more rapid initiation of coleoptile growth by 'Hycrest'. Radicle growth initiation for bluebunch wheatgrass was often equal to and sometimes more rapid than that of 'Hycrest'. Emergence success for 'Hycrest' (69%) was significantly higher than that of all but a few bluebunch wheatgrass accessions.

Regional patterns in seed size and germination and seedling responses were observed. Seeds from the Palouse Prairie were generally superior in the traits measured than those of any other region. Seeds from the Snake River Canyon Area were also large and relatively successful emerging. Seeds from Colorado were relatively small while seeds from Utah, Nevada, Idaho, and Montana were intermediate with no clear patterns in emergence success and seedling growth rate.

Results of experiments using 1993/95/96-collected seeds are partially analyzed. Seed weights varied significantly by collection site and by year, within a collection site (table 2). Data that will reveal within-population (among-plant) variability levels (95/96 seed collections) has not yet been analyzed. For each accession tested, mean maximum coleoptile lengths varied among sites and plants on a site (table 3). Within-plant variability was high enough to suggest that genetic control of this trait is rather loose. Among-accession differences in mean coleoptile length were great enough to suggest that this trait is probably responsible for a significant portion in the variability in emergence success observed in the depth seeding trial. Seed weight and maximum coleoptile length were not significantly correlated. Results of germination rate experiments were not available at the time this report was prepared.

Management Implications

Opportunities to improve seedling vigor, and subsequently establishment, of bluebunch wheatgrass are apparently available. Germplasm being considered for release in revegetation and restoration projects should be carefully screened for traits associated with seedling establishment success. Rigorous selection of promising bluebunch wheatgrass germplasm will likely result in improved seedling vigor for this species. When seeding bluebunch wheatgrass in a mix, care should be given to avoid excessive planting depth. Care should also be given to reduce excessive competition from faster-growing species such as the crested wheatgrasses. This is best accomplished by adjusting the seed mix. Existing literature provides ample evidence that bluebunch wheatgrass seedings (and most other species for that matter) on sites where competition from annuals such as cheatgrass and medusahead is excessive are not likely to succeed (Harris 1970, Harris 1977). Adequate measures to control weeds must be incorporated in the revegetation/restoration plan.

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Technology Transfer Products

Publications--

Kitchen, S.G. and S.B. Monsen. 1994. Germination rate and emergence success in bluebunch wheatgrass. J. Range Manage. 47: 145-150.

Plant Materials--

Results of bluebunch wheatgrass seedling vigor studies have been matched with drought tolerance studies and other evaluations of accession performance, including seed yield and competitive capacity against annuals. After careful evaluation of all data, we propose to release as a source identified, selected class germplasm an accession from near Anatone, Asotin Co. Washington (B-53). In our studies, this accession demonstrated superior seedling vigor and drought tolerance in comparison to 'Goldar', and also has earlier spring green-up. Seed production is excellent, for bluebunch wheatgrass, and seeds are large and, unlike 'Goldar' are approximately 50% awnless. We feel that this accession is well suited for the foothills and benches of southern Idaho, northern and central Nevada, and western and central Utah receiving 250 to 400 mm mean annual precipitation. Sites with fertile soils capable of supporting sagebrush/bunchgrass, mountain brush, pinyon/juniper, and bitterbrush/bunchgrass communities are included.

Table 1. Mean germination rate, emergence percentage, dry shoot weight (mg), and number of seeds per gram for select accessions of bluebunch wheatgrass and 'Hycrest' crested wheatgrass.

	Germination Rate Index		Deep Planting		
Germplasm	15/25° C	1° C	Emergence (%)	Dry Shoot Wt. (mg)	Num. of Seeds/g
Mean of all bluebunch WG	33.4	14.2	32	4.4	291
'Goldar'	51.2	17.8	47	8.4	201
B-53	34.8	20.5	66	9.5	228
'Hycrest'	47.1	26.8	69	12.2	----

Table 2. Mean number of seeds per gram for nine accessions of bluebunch wheatgrass collected from native parent populations and from common garden and nursery sites at Orchard, Idaho and Nephi and Spanish Fork, Utah from 1988 to 1993. Within accessions means, followed by the same letter are not significantly different at the $p<0.05$ level (SNK).

	Seed Collection Site and Year[1]				
Accession	P-88/89	P-93	0-93	N-93	S-93
	number of seeds per gram				
Levan, Ut.	316d	254c	233b	196a	196a
Provo, Ut.	262b	263b	------	------	217a
Brownlee, Id.	175b	173b	170b	175b	136a
Salmon, Id.	279c	250b	------	------	186a
Grand Ronde, Or.	298c	------	210b	164a	------
Asotin, Wa.	------	282b	286b	------	172a
Anatone, Wa. (B-53)	228c	------	205b	194a	186a
Meeker, Co.	356d	302c	------	236b	218a
Hamilton, Co.	356c	256b	------	214a	21 la

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[1] P-88/89 or P-93 = Parent site or naturally occurring population collected in 1988, 1989, or 1993. 0-93 = Orchard, Idaho common garden, 1993. N-93 = Nephi, Utah common garden 1993. S-93 = Spanish Fork, Utah nursery 1993.

Table 3. Mean coleoptile lengths for nine bluebunch wheatgrass accessions collected from native parent populations and from common garden and nursery sites at Orchard, Idaho and Nephi and Spanish Fork, Utah from 1993 to 1996.

	Seed Collection Site and Year[1]				
Accession	P-93	0-93	N-93	S-93	S-95/96
	length of coleoptile (mm)				
Levan, Ut.	32	36	37	34	34
Provo, Ut.	35	---	---	38	---
Brownlee, Id.	40	43	44	45	47
Salmon, Id.	37	---	---	37	---
Grand Ronde, Or.	---	43	44	---	---
Asotin, Wa.	38	36	---	37	---
Anatone, Wa. (B-53)	38	42	42	41	44
Meeker, Co.	36	---	44	43	---
Hamilton, Co.	41	---	42	40	37

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[1] P-93 = Parent site or naturally occurring population-1993 seed. 0-93 = Orchard, Idaho common garden-1993 seed. N-93 = Nephi, Utah common garden site-1993 seed. S-93 or S-95/96 = Spanish Fork, Utah nursery site- 1995 and 1996 seed.

Sandburg bluegrass Species Adaptability Studies

Stephen B. Monsen and Stephanie L. Carlson

Problem

Sandburg bluegrass (Poa secunda) is often regarded as a low or minimal important forage species, yet is a principal perennial bunchgrass common to the big sagebrush (Artemisia tridentata) and salt desert communities of the Intermountain region. It provides excellent early spring herbage, soil protection and stability to many arid sites, and effectively controls the spread and occurrence of annual weeds. It recovers well after fires, and is able to produce viable seeds even during years of drought. It is able to invade sites occupied by cheatgrass (Bromus tectorum), and can prevent the invasion of cheatgrass following fire if sites are protected form grazing. This species serves as an important pioneer species and allows the natural recruitment of native shrubs and herbs. The ecological relationship and phenological growth features of this plant are important to the survival and natural recruitment of many shrubs under arid situations. This species is important in the natural succession of disturbed communities, and becomes an important species in restoration programs. Disturbances of many native shrub/grass communities, including sites once occupied by Sandburg bluegrass have occurred throughout the Intermountain region. Weeds have often invaded and suppressed the recovery of native species. Many sites have been seeded to introduced perennial grasses to control weeds. Although many introductions are well adapted, recovery of native shrubs and herbs has been prevented. Reestablishing Sandburg bluegrass and other native perennials is required to restore desirable communities.

Restoration of the native grass/shrub communities is an important issue throughout the Snake River Plain of southern Idaho. To accomplish community restoration, under story species must be effectively restored. Various populations or ecotypes of Sandburg bluegrass appear to occur in this geographical region. It is important to determine if distinct ecotypes do actually occur, and if specific adaptive attributes may contribute to their survival and distribution. Development of commercial seed to restore extensive disturbances is dependent upon the selection of one or more ecotypes that are regionally adapted.

This study was initiated to collect and evaluate the principal ecotypes or populations of Sandburg bluegrass that exist throughout the Snake River Plain, determine if adaptive differences may occur, and advance one or a combination of selections for commercial production and seeding.

Methods

Between 1990 and 1992, seed of Sandburg bluegrass was collected from approximately 50 different locations, primarily from southern Idaho, but including areas in northern Utah and north eastern Nevada. Twenty-three different collections were reared under greenhouse conditions and transplanted at the Orchard, Idaho and Nephi, Utah study sites in the spring 1993 (Table 1). Plant survival and growth characteristics were recorded annually from 1994 to 1996. Phenological and morphological growth measurements were also taken to denote and record response to climatic and environmental conditions. Growth responses among accessions and among individuals of each accession were recorded to determine uniformity within and between selections. Vegetative growth, floral formation, and seed maturation were matched with climatic data to define response to seasonal growing conditions. Seed maturation data and vegetative growth attributes were collected to identify and characterize selections for potential seed production, forge production, and establishment characteristics.

Phenological growth responses were also measured using dark respiration and heat loss techniques to aid in the characterization of growth responses. These techniques were use in conjunction with field examinations to define and related growth to environmental stimuli. Results of the dark respiration and heat loss studies are reported in a separate section of this report.

Results and Discussion

Survival during the four-year period 1993-1996 indicate differences occurred among selections tested (Table 2). Although survival among selections planted does not appear to related to particular regions or elevation patterns, sufficient differences occur and confirm ecotypic adaptability does exist and can effect establishment and survival. Most sources collected from southern Idaho survived reasonably well at the Orchard study site, but conversely were not well adapted at the Utah site. Obviously, materials collected from southern Idaho was not adapted to situations in central Utah. Plantings are too young to expect extensive losses or response to cumulative climatic conditions. Plant establishment at the Orchard study site occurred during a period of extremely dry conditions, 1993-1995. The high survival rate among a number of selections is indicative of the excellent establishment and persistence features of young plants of this species (Table 2). Survival of most selections exceeded 90 percent the first season following planting. Survival declined slightly in 1995 and again in 1996 for some, but not all selections. Initial establishment is an important feature of this species, but response during the first 1-4 years should be carefully considered. Survival of a number of selections did not decline during this examination period. Materials collected from the Weiser/Middleton region generally survived slightly better than other locations. Although individual selections within other regions did not all respond similarly, materials collected from the Bruneau/Crows Nest area survived next best, followed by materials from Orchard/Mayfield; Grassmere; and Cambridge/Rogerson. Plant height, particularly leaf height is considered an import characteristics of this species. Considerable difference in plant statue is observed among of ecotypes throughout the Intermountain region, but differences may be due to seasonal or annual growing conditions. Based upon leaf height measurements taken in 1996 at the Orchard site, differences among accessions under study varied between 22.2 and 10.6 inches (Table 3). Taller accessions were Pose B31-92, Cambridge; Pose B4-90, Orchard; Pose B29-92, Weiser; Pose B8-91, Lindon; Pose B18-92, Blacks Creek; Pose B20-92, Mayfield; and Pose B25-92, Highland Valley. No discernable relationship exists between origin and plant statue, although accessions from higher elevations tend to produce tall upright plants. Plant height and vegetative growth is important in providing herbage and would appear important in providing competition to associated species. Plants have also been measured and ranked based on growth habit. Growth habit rankings ranging from low decumbent to erect, upright, clumps were used. No major differences in plant growth form has been recorded among collections.

Accessions were also rated for summer greenness; an important attribute related to seasonal forage quality, competition, and fire resistance. As may be expected, accessions originating from more upland sites tended to remain green longer into the summer months than accession obtained from lower elevations (Table 4). However, some accessions from lower elevations did retain excellent greenness, and provide material with late summer growth. Accessions with the most persistent or late summer growth were: Pose B29-92, Weiser; Pose B8-91, Lindon, UT; Pose B18-92, Blacks Creek Rd.; Pose B10-92 Snowville, UT; Pose B20-92, Mayfield; Pose B4-90, Orchard; Pose B14-92, Three Creek Well. Plant production and vigor rankings have also been taken in conjunction with greenness, this data is presented in Table 3.

In 1997, weekly phenological ratings were collected of 16 accessions at both Orchard and Nephi study sites (Table 5). Growth began approximately two weeks earlier at Orchard than Nephi. The beginning date at Orchard was March 5, and at Nephi March 18. At Orchard floral stems appeared by April 3, and significant elongation began on April 10. Stem growth at the Nephi site was approximately three weeks behind, with stocks present by April 21, and elongation beginning on April 28. Weekly measurements were continued until seeds were ripe and ready to collect. This date was May 22 at Orchard and May 27 at Nephi. Seeds generally reached maturity two weeks after maximum anthesis. Accessions that initiated and completed growth earlier at the Orchard study site were Pose B20-92, Mayfield; Pose B4-90, Orchard; Pose B21-92, Mayfield; Pose B29-92, Weiser; and Pose B7-90, Boise Rest Stop. No distinct pattern in growth can be attributed to origin. Existing data suggests there are some differences in plant growth characteristics among accessions presently under study, but differences are not very discernable. Material collected from Weiser, Idaho establish well, produce an abundance of leaves and seeds, and are quite competitive and vigorous. Ecotypes throughout the Snake River Plain appear to be genetically similar, and selection of a general ecotype would appear to be contain the genetic attributes to be adapted to this region. Based upon preliminary data, seeds have been collected from the Weiser and Mtn. Home sites for seed increase. In 1996, approximately 45 pounds of seed was harvested from the Saylor Creek Bombing Range. This is a central location of the Snake River Plain and appears to represent an ecotype suited to the general region. Seed has been entered into seed production fields at three locations consisting of approximately 15 acres.

Management Implications

A Source Selected ecotype of Sandburg bluegrass has been developed for planting throughout the Snake River Plain. The material has been extended into seed production fields for seed increase. Commercial seed should be available for wildland plantings by 1999.

Table 1. Sandburg bluegrass collection sites

Accession Number Collection Date	Location	County/State	Elevation (ft.)
POSE 3-90	Lockman Butte Res. Site	Elmore, ID	3145
POSE 4-90	Orchard Weather Station	Ada, ID	3452
POSE 5-90	Kuna Butte	Ada, ID	3100
POSE 7-90	Rest Stop SE of Boise I-84	Ada, ID	2800
POSE 8-91	Lindon	Utah, UT	4800
POSE 10-92	Rest Area N. of Snowville	Oneida, ID	4600
POSE 12-92	4 mi W of Rogerson	Twin Falls, ID	5400
POSE 14-92	4 mi N on 3 Cr Well to Bruneau Road	Owyhee, ID	5500
POSE 15-92	3 mi S. of Crows Nest Site	Owyhee, ID	4200
POSE 18-92	12 mi NE of I-84, Black Cr Rd	Elmore, ID	3500
POSE 20-92	24 mi NE of I-84, Mayfield Rd	Elmore, ID	3650
POSE 21-92	30 mi NE of I-84, Mayfield Rd	Elmore, ID	3600
POSE 23-92	Hwy 78, S of Murphy	Owyhee, ID	3400
POSE 25-92	Boise Front, Highland Valley Rd	Ada, ID	3200
POSE 26-92	N of Middleton	Canyon, ID	2525
POSE 29-92	Hwy 95 13 mi N of Weiser	Washington, ID	3100
POSE 31-92	19 mi W of Cambridge, Hwy 71	Washington, ID	2300
POSE 33-92	8 mi E of I-84, Oregon and Idaho State Line	Payette, ID	2300
POSE 34-92	Hwy 78, N of Orenna	Owyhee, ID	3000
POSE 36-92	W of Grasmere	Owyhee, ID	5126
POSE 39-92	Hwy 26, Bliss to Shoshone	Gooding, ID	3500
POSE 45-92	Hwy 93, Pagari Rd, NE of Richfield	Lincoln, ID	4400
POSE 47-92	Hwy 93, Jackpot to Wells, Boise Ranch	Elko, NV	5460

Table 2. Percent Survival for all accessions at the Orchard and Nephi study sites during 1994-1996.

	Orchard				Nephi			
	---Percent Survival---				---Percent Survival---			
Accession	'94	'95	'96	Rank[1]	'94	'95	'96	Rank[1]
POSE B29-92	100	100	100	1	93	100	93	1
POSE B8-91	96	96	92	2	96	92	1	23
POSE B14-92	96	96	92	3	100	85	29	16
POSE B26-92	92	87	92	4	96	87	37	11
POSE B15-92	96	96	87	5	100	83	37	10
POSE B20-92	92	96	87	6	100	79	25	17
POSE B39-92	92	92	87	7	92	83	32	14
POSE B4-90	87	87	83	8	96	96	71	2
POSE B34-92	96	87	83	9	96	67	33	13
POSE B36-92	83	83	83	10	92	92	67	4
POSE B45-92	83	83	83	11	96	58	17	19
POSE B10-92	87	87	79	12	100	82	70	3
POSE B21-92	96	96	79	13	100	96	16	20
POSE B33-92	79	83	79	14	87	79	21	18
POSE B23-92	86	78	78	15	68	55	4	21
POSE B7-90	79	79	75	16	96	87	29	15
POSE B31-92	75	75	75	17	96	92	62	5
POSE B12-92	83	79	71	18	100	96	50	7
POSE B18-92	87	75	71	19	86	64	1	22
POSE B3-90	75	75	67	20	96	92	37	8
POSE B47-92	92	87	58	21	96	83	54	6
POSE B5-90	62	58	54	22	92	79	37	9
POSE B25-92	71	33	37	23	38	40	35	12

[1] Rank - accession are ranked by survival in decreasing order based on 1996 data.

Table 3. Poa Secunda - Plant survival, height, crown, diameter in centimeters, and vigor ratings for all accessions at the Orchard and Nephi study sites for 1994, 1995, and 1996.

		% Survival			1994			1995				1996			
Species & Location	Study Site	'94	'95	'96	Vigor	Stalk ht	Crown	Vigor	Leaf ht	Stalk ht	Crown	Vigor	Leaf ht	Stalk ht	Crown
B3-90	Orchard	75	75	67	3.1	32.1	20.0	2.7	6.8	38.5	21.1	2.3	13.8	28.4	35.9
Lockman Butte, ID	Nephi	96	92	37	2.6	29.6	22.5	1.4	6.8	30.2	15.7	1.7	6.6	–	9.8
B4-90	Orchard	87	87	83	3.2	36.8	17.6	3.3	7.4	49.6	25.1	3.0	19.6	36.25	39.8
Orchard Site, ID	Nephi	96	96	^{2}71	2.9	34.3	23.1	1.8	9.0	42.7	16.9	3.1	10.7	23.0	15.0
B5-90	Orchard	62	58	54	3.3	30.5	21.6	2.5	6.7	38.0	17.7	2.3	14.0	27.0	33.2
Kuna Butte, ID	Nephi	92	79	37	2.5	27.7	24.0	1.8	7.4	28.4	15.2	2.0	7.5	–	11.5
B7-90	Orchard	79	79	75	3.3	35.0	15.6	3.5	7.6	49.1	31.7	2.8	17.6	34.3	43.6
Rest Stop, Boise, ID	Nephi	96	87	29	3.0	34.5	25.0	2.3	8.7	36.4	17.2	2.3	6.5	–	8.9
B8-91	Orchard	96	96	^{2}92	3.5	43.0	23.8	4.0	10.5	59.2	39.3	3.0	18.4	30.5	45.3
Lindon Burn, UT	Nephi	96	92	1	3.6	46.3	33.8	3.0	14.7	55.8	30.6	1.0	3.0	--	3.0
B10-92	Orchard	87	87	79	3.2	35.8	19.1	3.3	8.3	44.7	26.1	2.4	15.5	29.6	33.7
PJ Rest Stop, UT	Nephi	100	82	^{3}70	3.0	34.5	25.5	2.0	11.7	37.9	23.3	2.4	8.0	–	11.0
B12-92	Orchard	83	79	71	3.1	36.5	21.0	3.1	6.5	42.3	27.5	2.4	14.1	24.8	31.3
Rogerson, ID	Nephi	100	96	50	2.8	34.1	22.8	2.0	9.3	38.3	20.2	2.0	6.8	–	10.3
B14-92	Orchard	96	96	^{3}92	3.7	38.8	25.3	3.5	6.6	51.8	30.2	2.5	14.8	31.1	37.2
3 Creek Well, ID	Nephi	100	85	29	2.8	32.7	22.1	2.2	7.3	40.3	14.8	2.3	8.1	–	11.5
B15-92	Orchard	96	96	^{5}87	3.3	37.9	17.9	3.1	7.0	44.5	20.4	1.9	16.5	29.7	32.4
Crows Nest, ID	Nephi	100	83	37	2.9	31.7	21.5	1.5	7.3	34.5	15.3	2.0	5.1	--	8.2
B18-92	Orchard	87	75	71	3.3	37.3	15.2	3.4	9.2	47.9	45.6	3.0	17.1	31.3	41.4
Blacks Creek Rd, ID	Nephi	86	64	1	2.6	34.0	15.9	1.7	10.1	35.6	18.5	3.0	8.0	–	11.0
B20-92	Orchard	92	96	87	3.3	38.0	22.2	3.6	9.2	48.4	33.2	3.3	17.1	34.7	43.8
Mayfield Rd, ID	Nephi	100	79	25	2.9	33.9	26.0	1.7	8.4	38.1	14.5	2.2	7.9	–	9.5
B21-92	Orchard	96	96	79	3.7	42.7	23.4	3.5	8.5	47.1	33.3	2.7	15.8	34.3	42
Baseline Rd, ID	Nephi	100	96	16	3.1	35.7	27.4	2.7	11.2	37.4	23.7	1.2	6.0	–	5.8

Table 3. Poa Secunda - Plant survival, height, crown diameter in centimeters, and vigor ratings for all accessions at the Orchard and Nephi study sites for 1994, 1995, and 1996.

		% Survival			1994			1995				1996			
Species & Location	Study Site	'94	'95	'96	Vigor	Stalk ht	Crown	Vigor	Leaf ht	Stalk ht	Crown	Vigor	Leaf ht	Stalk ht	Crown
B23-92	Orchard	86	78	78	3.2	34.4	16.5	2.8	7.3	37	22.1	2.1	13.1	23.5	32.2
Hwy 78, Grandview, ID	Nephi	68	55	4	2.9	32.6	19.7	1.8	8.3	29.7	17.0	1.3	7.0	–	10.3
B25-92	Orchard	71	33	37	2.8	31.5	14.2	2.7	7.5	42.7	21.7	2.4	18.0	32.3	36.6
Boise Front, ID	Nephi	38	40	35	3.0	35.0	31.4	2.3	9.0	40.4	17.7	3.3	10.9	–	15.5
B26-92	Orchard	92	87	^{4}92	3.5	34.8	18.8	3.1	8.1	42.9	28.7	2.3	14.9	25.9	34.4
Middleton, ID	Nephi	96	87	37	2.6	27.6	20.3	2.12	8.2	34.2	20.0	2.0	7.2	–	10.1
B29-92	Orchard	100	100	^{1}100	3.3	37.4	18.8	4.2	14.1	54.8	39.2	3.9	19.2	38.8	49.8
E. Weiser, ID	Nephi	93	100	^{1}93	3.1	38.2	16.4	2.5	11.9	51.5	16.5	2.8	8.4	–	11.6
B31-92	Orchard	75	75	75	3.0	32.0	15.8	3.0	8.9	37.0	23.3	2.6	22.2	26.3	34.0
Hells Canyon, near Brownlee Dam, ID	Nephi	96	92	^{5}62	2.7	31.0	21.4	2.4	11.1	30.2	23.2	2.8	9.1	–	12.3
B33-92	Orchard	79	83	79	3.1	33.1	17.7	3.3	6.6	47.0	27.1	2.6	15.2	30.7	43.6
I-84, OR/ID State Line, ID	Nephi	87	79	21	2.7	30.0	20.5	2.1	7.8	37.1	18.2	2.2	10.8	–	13.6
B34-92	Orchard	96	87	83	3.3	33.2	18.1	2.7	6.6	37.5	23.1	1.7	10.6	22.2	26.6
Hwy 78 - Murphy, ID	Nephi	96	67	33	2.7	30.4	24.2	1.5	6.6	31.7	14.4	1.4	6.8	–	8.4
B36-92	Orchard	83	83	83	3.6	38.0	24.1	3.2	6.8	48.6	31.1	2.3	16.9	28.8	35.2
Grasmere, ID	Nephi	92	92	^{4}67	2.8	32.2	21.3	1.7	7.8	38.2	16.8	2.4	7.4	19.7	11.1
B39-92	Orchard	92	92	^{5}87	3.2	36.1	16.6	3.0	8.3	35.4	25.8	2.5	14.5	28.8	40.7
Gooding, ID	Nephi	92	83	32	2.5	31.6	17.2	1.5	6.6	25.0	14.1	2.2	7.4	–	8.4
B45-92	Orchard	83	83	83	3.1	34.4	13.4	3.1	5.9	46.4	31.2	2.4	15.9	29.6	35.9
Hwy 93, Nof Richfield, ID	Nephi	96	58	17	3.0	31.5	21.6	1.8	6.8	35.7	17.7	2.3	7.9	–	11.0
B47-92	Orchard	92	87	58	3.4	30.8	22.9	3.0	6.2	41.4	28.1	1.7	13.7	21.7	24.8
Jackpot to Wells, NV	Nephi	96	83	54	2.8	27.4	18.6	1.8	7.8	33.2	18.8	2.5	7.2	–	10.5

Subscript 1-5 rank top surviving sources based on 1996 data.

Table 4. Summer greenness rankings for 23 accessions of Sandburg bluegrass at Orchard and Nephi study sites for 1995 and 1996

	1995				1996			
Ranking	Nephi		Orchard		Nephi		Orchard	
1	B29	2.3 a	B29	3.5 a	B18	4.0 a	B29	4.2 a
2	B10	1.7 b	B18	2.9 b	B29	3.4 ab	B18	3.3 b
3	B31	1.6 bc	B8	2.7 bc	B10	3.0 abc	B8	3.3 b
4	B25	1.6 bcd	B39	2.4 c	B31	3.0 abc	B45	2.8 c
5	B21	1.4 bcde	B31	2.4 c	B8	3.0 abc	B10	2.8 c
6	B20	1.4 bcde	B10	2.3 cd	B14	3.0 abc	B20	2.8 c
7	B4	1.4 cdef	B23	2.3 cd	B4	3.0 abc	B4	2.7 c
8	B14	1.3 def	B20	2.3 cd	B34	3.0 abc	B21	2.6 cd
9	B8	1.3 def	B21	2.2 cd	B25	3.0 abc	B14	2.6 cd
10	B7	1.3 def	B34	1.9 de	B47	2.9 abc	B7	2.6 cd
11	B18	1.3 def	B26	1.8 e	B21	2.7 abc	B31	2.2 de
12	B5	1.2 ef	B3	1.7 ef	B15	2.6 abc	B3	2.2 de
13	B47	1.2 ef	B7	1.7 ef	B7	2.4 abc	B33	2.1 e
14	B12	1.1 ef	B45	1.6 ef	B39	2.4 abc	B12	2.1 e
15	B33	1.1 ef	B25	1.5 ef	B20	2.4 abc	B15	2.0 e
16	B26	1.1 ef	B47	1.5 ef	B12	2.3 abc	B39	2.0 e
17	B23	1.1 f	B12	1.5 ef	B36	2.3 abc	B25	2.0 e
18	B3	1.1 f	B4	1.4 ef	B3	2.2 abc	B23	1.9 e
19	B34	1.0 f	B36	1.3 f	B5	2.1 bc	B47	1.9 ef
20	B15	1.0 f	B15	1.3 f	B23	1.7 bc	B26	1.9 ef
21	B45	1.0 f	B5	1.3 f	B45	1.6 bc	B5	1.7 ef
22	B39	1.0 f	B14	1.2 f	B26	1.5 bc	B3	1.7 ef
23	B36	1.0 f	B33	1.2 f	B33	1.3 bc	B34	1.4 f

Different letters are significant at $p<0.05$.

Table 5. Phenological stages of growth recorded in centimeters at weekly intervals in 1997 for 16 accessions of Sandburg bluegrass at Orchard and Nephi study sites.

DATES:	Orchard Nephi	3/5		3/13		3/20 3/18		3/27 3/24		4/3 3/31			4/10 4/7			4/18 4/14			4/24 4/21			5/1 4/28		
Species	Study Site	Leaf Height	Crown	Leaf Height	Crown	Leaf Height	Crown	Leaf Height	Crown	Leaf Height	1= No 2=Yes Stem	Crown	Leaf Height	Stem Height	Crown	Leaf Height	Stem Height	Crown	Leaf Height	1= No 2= Yes Stem	Crown	Leaf Height	Stem Height	Crown
B4-90	Orchard	11.3	12.1	12.3	18.1	17.0	20.6	20.0	23.5	19.5	2	24.9	20.0	11.8	24.5	21.9	18.9	25.0	21.5	24.1	24.4	22.4	33.1	23.2
	Nephi					7.6	14.8	9.6	15.3	9.7		15.8	10.4		19.2	11.8		21.4	14.7	2	21.9	17.1	17.3	26.5
B5-90	Orchard	8.1	10.8	8.4	17.9	12.4	18.4	14.5	19.5	14.4	2	20.4	13.9	12.3	18.7	16.3	17.3	17.9	14.2	15.6	17.3	14.8	15.6	19.7
	Nephi					4.6	10.1	6.2	11.96	6.5		12.1	6.7		13.4	6.9		14.3	8.4	2	16.0	10.0	16.0	19.5
B7-90	Orchard	10.3	14.8	12.6	22.9	15.6	23.8	19.2	25.9	19.8	2	29.1	16.8	10.5	23.7	18.8	15.0	24.3	19.3	20.5	29.2	21.0	24.0	26.8
	Nephi					5.8	10.0	7.5	11.37	8.1		12.8	8.7		15.7	9.5		15.1	11.4	2	16.8	12.7	16.4	19.3
B10-92	Orchard	7.4	9.2	9.6	16.8	13.4	19.6	15.8	22.9	17.6	2	23.3	18.5	12.1	23.9	16.8	13.7	20.1	15.4	15.8	20.3	15.3	18.9	22.3
	Nephi					4.6	11.3	5.8	12.7	6.9		13.2	7.7		14.8	8.8		15.1	11.8	2	17.4	13.3	15.3	19.4
B12-92	Orchard	7.8	11.2	9.0	17.5	11.4	19.6	13.6	19.8	14.9	2	22.7	15.7	11.7	21.1	14.4	14.6	22.1	14.6	17.4	20.5	15.3	22.96	21.7
	Nephi					5.2	12.8	6.0	13.8	6.8		14.7	7.4		16.8	7.5		16.9	9.4	2	18.4	10.4	14.5	19.6
B14-92	Orchard	6.5	9.5	7.8	17.2	10.4	18.5	12.6	21.1	14.0	2	22.8	13.1	10.0	19.9	14.9	10.7	19.5	13.7	18.2	22.9	13.2	24.6	21.6
	Nephi					3.8	8.9	5.3	10.8	6.0		11.2	6.5		12.8	6.9		12.9	8.8	2	14.2	10.7	12.4	17.6
B15-92	Orchard	8.0	10.2	8.7	15.4	11.8	16.5	14.8	19.3	17.5	2	22.0	16.7	11.5	18.5	16.1	15.1	20.0	17.5	14.0	20.4	16.7	18.1	20.6
	Nephi					4.9	10.4	6.0	11.6	6.8		12.0	7.1		13.5	7.5		13.7	9.4	2	15.5	10.2	14.6	16.0
B18-92	Orchard	8.4	13.5	11.5	20.7	13.0	21.7	16.7	24.8	16.8	2	26.2	16.4	11.9	25.6	18.8	16.0	25.6	16.0	21.9	27.1	17.4	22.6	27.0
4 plts	Nephi					4.0	6.7	5.2	8.5	5.5		8.5	5.7		10.0	6.0		8.5	7.0	2	9.7	9.0	10.0	11.3
B20-92	Orchard	12.2	16.1	14.3	24.9	16.2	22.0	18.3	25.9	21.121.	2	30.1	21.66	11.7	26.2	21.2	16.0	24.6	19.4	18.0	25.4	20.6	22.3	27.2
	Nephi					4.4	8.3	5.9	11.9	6.9		11.8	7.0		13.0	7.9		14.9	9.4	2	16.6	10.2	14.4	17.1
B21-92	Orchard	11.3	13.6	12.4	21.6	15.4	20.8	19.9	23.9	19.1	2	26.9	20.1	16.0	23.8	21.3	19.1	24.7	19.3	23.7	22.6	18.2	27.1	22.8
6 plts	Nephi					2.8	5.8	4.1	6.8	4.5		7.3	5.0		9.8	5.7		8.5	6.7	2	9.2	6.3	15.0	9.7
B23-92	Orchard	6.2	10.4	7.3	17.3	10.8	19.2	12.5	19.0	15.0	2	21.8	14.4	11.5	18.0	15.4	13.1	16.7	13.5	15.5	18.2	14.2	15.0	18.7
6 plts	Nephi					2.8	6.7	4.3	8.2	5.2		8.0	5.3		8.5	5.3		8.8	6.8	2	9.7	7.8	12.0	11.0
B26-92	Orchard	8.1	12.6	10.6	21.0	12.6	21.8	14.1	23.4	14.6	2	26.5	15.7	10.4	25.1	17.2	14.6	25.8	15.9	20.1	25.8	17.3	20.4	25.4
	Nephi					4.0	9.8	5.6	9.9	6.1		11.8	7.2		14.3	7.0		13.4	9.7	2	15.2	10.4	14.0	18.9
B29-92	Orchard	11.3	15.9	12.3	21.8	17.4	24.1	20.4	27.44	22.2	2	33.6	23.6	13.7	31.6	25.2	17.6	29.6	23.2	24.6	37.3	24.9	34.0	31.2
7 plts	Nephi					5.3	9.8	6.5	11.4	7.8		13.4	8.2		15.4	8.3		13.7	10.7	2	16.6	13.1	15.5	16.9
B31-92	Orchard	7.6	13.4	8.9	21.2	12.0	23.4	15.8	23.4	16.3	2	28.8	16.4	13.7	25.9	17.4	15.8	25.6	16.1	15.0	22.0	18.2	16.4	24.2
	Nephi					5.1	10.9	5.8	12.7	8.3		14.1	8.7		16.4	9.1		16.9	11.6	2	18.8	14.0	18.2	23.6
B33-92	Orchard	10.1	15.6	11.0	21.7	13.1	20.2	15.7	22.9	17.6	2	24.9	17.7	10.44	24.2	18.3	13.9	24.6	17.0	19.1	24.3	17.7	18.7	26.0
	Nephi					4.7	9.6	5.8	11.3	6.7		11.7	7.0		14.5	7.5		13.7	9.6	2	15.7	11.2	14.1	19.2
B36-92	Orchard	8.1	10.0	10.6	20.3	13.1	20.9	14.8	21.3	17.0	2	25.6	17.7	11.9	20.7	18.0	16.7	24.2	15.3	21.9	27.227.	17.4	28.528.	22.9
	Nephi					5.6	12.3	6.7	13.2	7.1		14.9	7.2		15.8	8.1		16.3	9.7	2	17.6	11.2	14.4	20.4

Table 5. Continued

DATES:	Orchard Nephi	5/8 5/5			5/15 5/13				5/22 5/20					5/27	
Species	Study Site	Leaf Height	Stem Height	Crown	Leaf Height	Stem Height	Crown	1 = No 2 = Yes Anthesis	Leaf Height	Basil leaves	Stem Height	Crown	1 - No 2 - Yes Anthesis	Stem Height	Crown
B4-90	Orchard	20.7	31.7	27.6	19.0	37.3	28.2		20.4		36.0	28.0			
	Nephi	19.1	25.1	33.1	19.3	33.29	37.6	1		10.3	36.9	37.5	2	39.0	41.2
B5-90	Orchard	14.2	14.4	17.3	12.6	17.3	17.4		14.1		15.3	14.6			
	Nephi	10.7	19.0	21.6	11.5	26.3	22.9	2		6.6	25.2	22.7	2	27.9	25.9
B7-90	Orchard	19.0	24.7	29.0	16.8	27.7	27.9		18.9		27.3	30.0			
	Nephi	14.0	22.7	23.1	14.1	30.1	25.5	1		10	32.9	28.7	2	35.4	29.5
B10-92	Orchard	13.7	19.7	19.6	14.2	21.1	19.4		16.8		21.4	23.0			
	Nephi	14.2	21.9	22.5	14.5	30.4	25.7	1		9.1	35.1	28.2	2	36.5	31.0
B12-92	Orchard	15.0	20.6	23.8	12.3	21.4	22.2		17.0		28.2	21.9*			
	Nephi	11.1	20.5	22.6	11.1	28.8	25.4	1		8.7	33.0	27.8	2	36.3	28.6
B14-92	Orchard	13.0	25.1	21.1	10.1	28.3	19.7		14.7		26.4	20.5			
	Nephi	11.5	18.5	20.3	12.0	27.5	24.7	2		7.9	32.7	27.1	2	35.8	31.7
B15-92	Orchard	15.0	19.3	20.2	14.3	20.0	18.3		15.3		20.5	19.1			
	Nephi	10.2	20.1	18.2	10.1	27.4	19.7	2		7.1	31.1	21.7	2	33.3	22.3
B18-92 4 plts	Orchard	18.7	25.0	25.8	16.2	29.0	25.6		19.3		28.4	23.5			
	Nephi	8.3	16.0	12.0	8.0	—	12.0			8.0	—	12.0	2		12.02
B20-92	Orchard	20.0	25.1	27.5	19.7	24.0	27.0		20.5		25.0	27.3			
	Nephi	11.8	21.3	18.2	12.3	28.4	20.2	1		8.4	31.9	21.4	2	32.9	23.2
B21-92 6 plts	Orchard	19.1	26.4	29.8	17.0	28.7	25.2		20.1		31.1	25.6			
	Nephi	6.2	21.0	10.8	6.3	26.3	9.0	1		6.7	28.3	11.8	2	28.7	11.7
B23-92 6 plts	Orchard	12.2	13.7	19.4	11.2	15.8	14.7		12.3		16.5	16.7			
	Nephi	8.0	16.4	12.2	7.7	21.4	15.5	2		5.7	24.2	15.0	2	24.8	17.7
B26-92	Orchard	17.5	23.7	25.7	15.2	20.7	26.7		14.9		21.7	25.0			
	Nephi	11.1	19.7	23.2	11.1	25.4	28.7	1		7.2	29.7	29.7	2	29.9	33.7
B29-92 7 plts	Orchard	23.7	34.8	36.6	21.8	35.7	34.2		23.5		26.0	37.1			
	Nephi	12.1	21.0	16.7	12.9	30.4	24.3	1		10.9	36.8	26.7	2	40.2	30.0
B31-92	Orchard	16.9	15.5	25.6	14.1	15.3	22.0		15.2		16.5	20.66			
	Nephi	15.4	24.2	28.6	15.6	31.4	31.8	1		9.5	33.8	34.3	2	34.7	37.7
B33-92	Orchard	17.1	24.9	29.0	15.8	22.5	23.2		18.1		19.2	23.2			
	Nephi	11.6	19.8	24.6	11.9	26.6	24.6	1		7.4	31.2	25.8	2	31.4	29.3
B36-92	Orchard	15.4	26.6	24.0	14.6	30.7	25.725.		16.1		32.4	23.7			
	Nephi	12.7	21.1	25.5	13.2	30.6	30.5	2		8.5	34.2	32.9	2	37.7	36.3

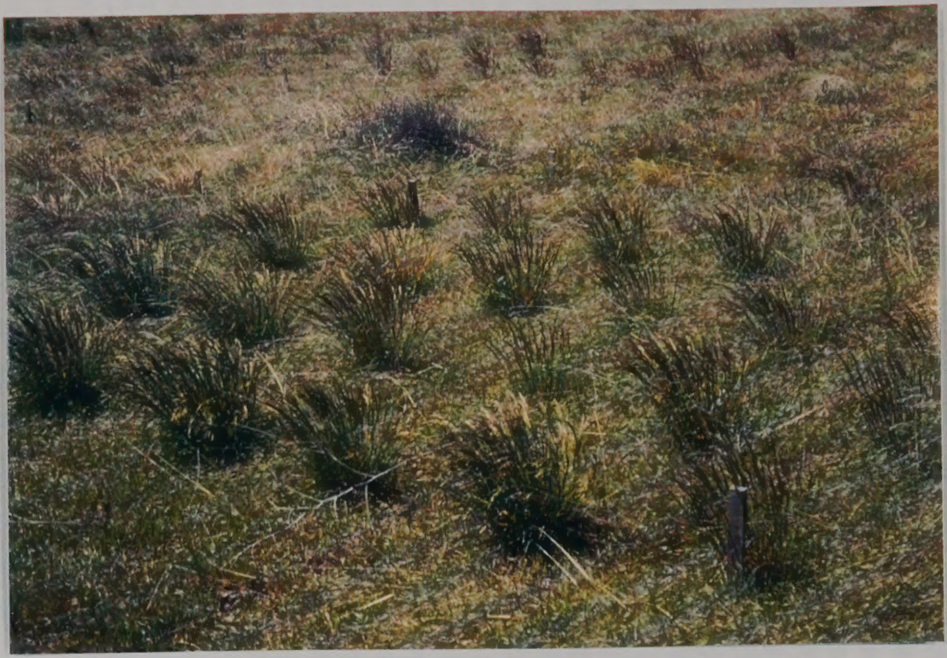

Figure 1. Sandberg bluegrass plot at Orchard.

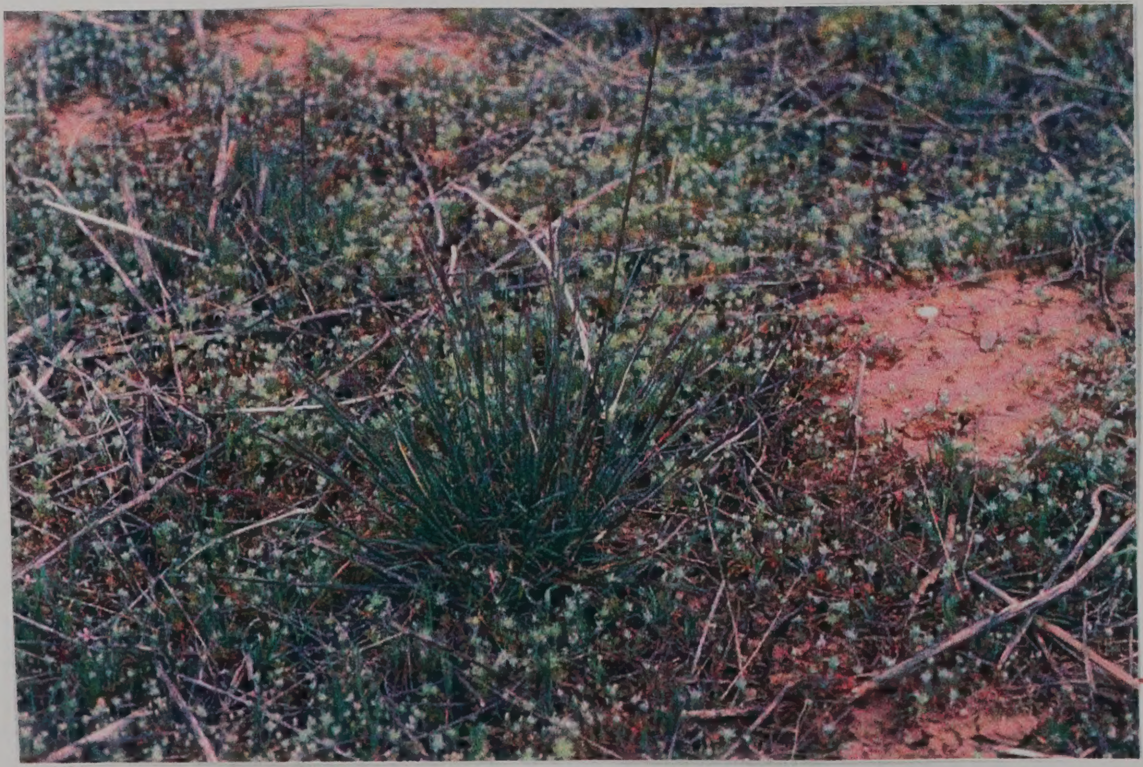

Figure 2. Sandberg bluegrass, Pose B20-92 at Nephi, Utah. Close up of individual plant.

Ecotypic Selection and Development of Thurbers Needlegrass

Stephen B. Monsen and Stephanie Carlson

Problem

Thurbers Needlegrass (Stipa thurburiana) is a perennial bunchgrass that occurs as a principal component of the wyoming big sagebrush (Artemisia tridentata spp. wyomingensis) communities of southern Idaho. Plants are particularly adapted to semi arid conditions in this region. This species occurs with Sandburg bluegrass (Poa secunda) and is highly effective in suppression and control of annual weeds. Leaves remain green into late summer. This is an important feature. Plants are able to continue growth and compete favorably with cheatgrass (Bromus tectorum). The green foliage provides excellent grazing when other species are dry. Initial studies demonstrate some seed dormancy, and stand establishment is more erratic than other more commonly seeded species. However, plants persist and spread satisfactory under natural conditions.

This grass evolved with plants common to the big sagebrush type. Consequently, this species tends to favor or facilitate natural recruitment of associated species. Reestablishment of this under story species is critical to the restoration of native communities. Studies were initiated in 1990 to collect various populations of Thurbers needlegrass that occurred in the Snake River Plain and evaluate general growth habits and agronomic traits of the species. In addition, floral and vegetative growth characteristics were evaluated to determine if ecotypic populations existed and were site adapted.

Methods

Seeds were collected from selected populations in 1989 and 1991, grown under greenhouse conditions and field planted at the Orchard and Sailor Creek study sites in the spring of 1990 and 1992. Plants have been evaluated annually to measure and record survival, vegetative growth, floral formation, summer greenest and vigor. In addition, dark respiration and heat loss measurements were recorded among accessions to determine if these measurements could be used to select individuals or populations with ability to persist under drought stress and stress from high temperatures.

Results and Discussion

Data from field evaluations has not been compiled and analyzed. Data from respiration and heat loss studies is presented in a following section. Comparative growth studies including survival and rate of growth demonstrate this species is slow to establish, but seedlings are extremely hardy and able to withstand competition. Differences in seedling establishment survival were recorded among accessions at both study sites. Annual plant growth rate and plant statue did not differ appreciably among the separate accessions. Based upon initial data, a selection from Orchard, Idaho has been extended into seed production. This selection is currently being promoted for release as a Source Selected item. Additional studies related to seed germination, seedling establishment, and comparative traits need to be completed to support release of this accession.

Management Implications

Studies have demonstrated Thurbers needlegrass can be used in restoration of wyoming big sagebrush ranges. Seedlings establish slowly, but persist well with weedy competition. Sufficient difference exists among different populations to justify selection and development of specific cultivars. A source identified cultivar is being produced for use in southern Idaho.

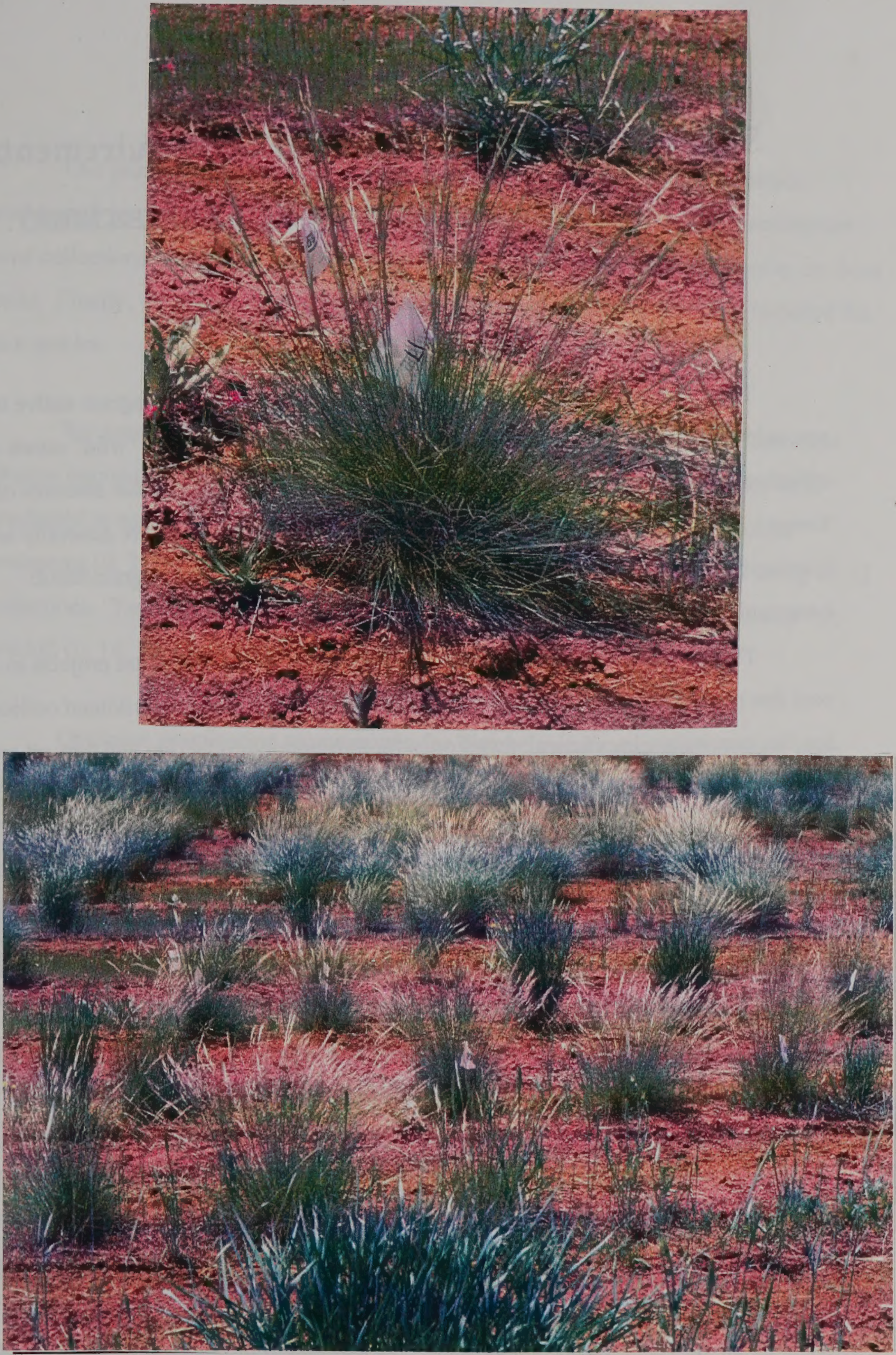

Figure 1. Thurbers Needlegrass STTH B2-91. Genral picture of plot 209 and closeup of plant number four at Nephi, Utah.

Seed Dormancy and Germination Requirements for Thurber Needlegrass (Stipa thurberiana)[1]

Stanley G. Kitchen and Stephen B. Monsen

Introduction

Thurber needlegrass (Stipa thurberiana) is an important bunchgrass native to semiarid regions of the Pacific Northwest. When properly managed, 'wild' stands are effective in suppressing weedy annuals and generally produce moderate amounts of forage. Thurber needlegrass is found in dense stands (though these are generally small in size) and as a significant componant of mixed bunchgrass and bunchgrass/shrub communities.

Thurber needlegrass seeds have not been included in restoration projects in the past due primarily to lack of seed availability. Although significant wildland collections for this species are impractical, techniques for agronomic production and harvest are being developed (Kitchen and Monsen 1998) and commercial production fields have been established. We anticipate that commercial quantities of Thurber neddlegrass seed will soon be available to land management agencies for use in seeding projects.

An understanding of seed dormancy and germination patterns for Thurber needlegrass seeds will assist agency personel in developing appropriate seeding methods (e.g. seeding rates) and meaningful expectations for measuring seeding success. In addition, reliable seed testing standards are needed to support marketing of this species. Prior to our work, little was known concerning seed dormancy and germination requirements for this or other closely related species, however, testing standards have been developed for two members of the genus, green needlegrass (S. viridula) (Rubida and Gutormson 1988) and needle-and-thread grass (S. comata) (Kitchen and others 1998). High levels of seed dormancy in these and related species (i.e. Oryzopsis spp.) reinforce the decision to evaluate seed germinability for Thurber needlegrass.

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[1] A detailed report of this study will be prepared for publication in *Seed Technology*. We anticipate publication will be in the spring of 1999.

Objectives

Our primary objective was to evaluate primary dormancy and germination response to incubation temperature, light, and prechill for several Thurber needlegrass seed collections. Secondly, we desired to assess the effect of seed after-ripening on these traits. Finally, we determined to assist in developing a uniform seed testing standard for this species.

Methods

We assembled 52 collections of Thurber needlegrass seeds from 28 Idaho and Oregon populations between 1988 and 1995. In 1993, laboratory experiments were conducted to assess germination response of recently-harvested seeds to prechill treatments (0, 35, and 70 days). Additional tests were conducted in 1996-97 using all 52 collections. Treatments included variable incubation temperatures (10/20 - 20/30° C), prechill (0, 14, 35, and 70 days), and light vs dark.

Results and Discussion

Optimum germination temperatures for Thurber needlegrass germination were 10/20 and 15/25° C. Light (12-hr photoperiod) produced significantly lower germination percentages than those produced by dark controls for eight of 10 collections. After-ripened collections were less sensitive to incubation temperature and light than recently-harvested collections. Germination responses for 20 recently-harvested seed collections representing 10 populations (collected 1993 and 1995) to 0, 35, and 70 days of prechill are seen in table 1. Mean germination for the no-prechill treatment was 70 and 77 percent for 1993 and 1995 collections, respectively. Response to prechill treatments varied by collection site and year of collection. Overall prechill was not a reliable treatment for reducing seed dormancy for this species. Differences in initial dormancy and germination response (no prechill) due to seed age (after-ripening) can be observed in table 2. Germination ranged from 24 to 89 percent for 15, recently-harvested (1995) collections. Germination percentages for seeds collected from the same populations in 1993 and 1994 are consistantly higher than those for 1995 indicating a gradual loss of dormancy over time.

Thurber needlegrass seeds were much less able to germinate at near freezing temperatures than were seeds of bluebunch and Snake River wheatgrasses (data on file). Mean germination at the end of 10 weeks of chilling (2° C prechill treatment) was less than three percent for Thurber wheatgrass compared to values greater than 90 percent for the two wheatgrass species. This suggests that Thurber needlegrass is more at risk to seeding failure when rapid soil crusting is a problem.

Management Implications

When seeding recently-harvested seeds, managers and seed growers should expect a small to moderate fraction of the seed to persist in the soil ungerminated. After-ripened seed is less likely to have this result, and if it does, the fraction will likely be quite small. Prechilling seeds (or natural stratification associated with fall-planting) will probably not have a significant impact on reducing seed dormancy. In fact, it might actually serve to induce secondary dormancy in some lots. Field germination and emergence studies could varify these predictions and should be conducted as a followup to this work.

Literature Cited

Kitchen, S.G. and S.B. Monsen. 1998. Thurber needlegrass and bottlebrush squirreltail seed production as affected by field rearing practices. Published as a part of this report.

Kitchen, S.G., R. Stevens, and G.R. Wilson. 1998. Addition of *Hesperostipa comata*--needle-and-thread grass to the Rules. Seed Technologist Newsletter 72: 139-143.

Rubida, A.L., T.J. Gutormson. 1988. Determining viability of green needlegrass (Stipa viridula Trin.). Journal of Seed Technology 12: 114-119.

Technology Transfer Products

Data from this study were used in an effort to develop a uniform standard for testing Thurber needlegrass seeds. This standard was incorporated into a rule proposal that was published in the Association of Official Seed Analysts (AOSA) and Society of Commercial Seed Technologist (SCST), *Seed Technologist Newsletter* in February 1998. Acceptance of this proposal will be considered in the AOSA/SCST annual meeting in June 1998.

Kitchen, S.G, R. Stevens, and G.R. Wilson. 1998. Addition of *Achnatherum thurberianum*--Thurber needlegrass to the Rules. Seed Technologist Newsletter 72: 144-148.

Table 1. A comparison of Thurber needlegrass seed germination for 10 collections made during two separate seasons. Tests were conducted within 9 months of collection dates both seasons. Percentages are adjusted for viability.

		Weeks of Prechill		
Collection Site	Coll. Year	0	5	10
		----- germination percentage -----		
Lucky Peak Nursery, Idaho	1993	54	36	73
	1995	87	100	98
SE of Boise, Idaho	1993	97	86	95
	1995	81	91	99
Old Hwy and Baseline Road, Idaho	1993	84	72	88
	1995	70	81	86
Danskin Road, Idaho	1993	51	37	84
	1995	89	83	95
Mayfield Road, Idaho	1993	98	92	98
	1995	88	100	100
Orchard, Idaho	1993	55	46	79
	1995	82	87	95
Eagle, Idaho	1993	57	60	84
	1995	63	69	88
Emmett, Idaho	1993	58	74	87
	1995	75	84	87
Brownlee Dam, Idaho	1993	67	73	94
	1995	54	99	100
Richland, Oregon	1993	74	49	64
	1995	78	91	98

Table 2. Seed germination for Thurber needlegrass collections made during three successive years. All collections were tested in the spring of 1996 at 10/20 C for 28 days. Germination percentages are adjusted for seed viability.

	Year of Seed Collection		
Collection Site	93	94	95
	----- germination percentage -----		
Lucky Peak Nursery, Idaho	89	96	87
SE of Boise, Idaho	100	---	81
Old Hwy and Baseline Road, Idaho	99	83	70
Baseline Road, Idaho	100	---	73
Danskin Road, Idaho	100	100	89
Mayfield Road, Idaho	100	100	88
Orchard, Idaho	90	---	82
Eagle, Idaho	97	---	63
Kuna Butte, Idaho	---	73	71
Emmett, Idaho	93	---	75
Brownlee Dam, Idaho	100	---	54
Thorne Creek, Idaho (1)	---	56	24
Thorne Creek, Idaho (2)	---	84	40
Carey, Idaho	---	92	53
Richland,Oregon	100	---	78

Performance of Yarrows

Stephen B. Monsen and Stephanie Carlson

Problem

Western yarrow (Achillea millefolium ssp. lanulosa) is a perennial forb with circumboreal distribution. It is an important understory species in big sagebrush (Artemesia tridentata) communities of the West where annual weeds have invaded and extensive fires now occur. Restoration of these communities with a balanced assembly of native species would reduce fire related problems, restrict the spread and establishment of weeds, and provide more stable and productive ecosystems.

Yarrow ecotypes are adapted to a wide range of plant communities and climatic conditions. Some native ecotypes are adapted to arid conditions where few other species occur. Some Eurasian species of this genus have demonstrated adaptation and value for use on semiarid sites.

Western yarrow is recognized for its ability to establish with minimal seedbed preparation. It is one of the few broadleaf herbs that can be successfully seeded on sites occupied with some annual weeds. It appears important in improving the stability and natural regeneration of some shrub/steppe communities. Foliage remains green until mid summer, providing sufficient greenness to restrict the spread of ground fires. Because of these traits, studies were instigated to investigate the utility of different native yarrow ecotypes and a select assembly of introduced yarrow species for use in greenstrip and weed control plantings. In addition, native ecotypes were evaluated for their adaptability and use in restoration of big sagebrush communities.

Methods

Seeds of 29 different yarrow collections, 8 native and 21 introduced were collected during the summer of 1988 (Table 1). The planting included a number of selections previously evaluated in Utah for production of forage and cover on low foothill ranges. Seedlings of each were grown under greenhouse conditions during fall and winter 1988-89. They were transplanted in spring 1989 at the Orchard, Idaho and Nephi, Utah study sites. Each accession was planted in three plots at each site with 24 plants in each plot arranged in a four by six plant grid. Plots at each site were arranged in a completely randomized block design at each site. Approximately 4,200 seedlings were planted in these studies.

Plantings were established in areas tilled to reduce weeds, but limited weeding was conducted following planting; seedlings were allowed to compete with weeds to permit natural spread, competitive responses, and mortality to occur. Burning trials have been conducted to determine resprouting and flammability characteristics. Summer greenness ratings and water content data were collected weekly for all accessions in 1994. Plantings were examined to determine the ability of individual collections to restrict or prevent the growth and occurrence of understory weeds. Annual ratings were taken to determine adaptability, particularly summer greenness and fire tolerance.

Results and Discussion

Survival of all yarrow species and accessions were considerably higher at the Nephi planting site than at Orchard (Table 2). Initial establishment and survival was high for nearly all selections at both locations for the first two to three years after planting. A rapid decline in plant survival, particularly of the more mesic species, occurred at the Orchard site beginning in 1991 and continued through 1993. Most species continued to decline, though more slowly, from 1993 until 1995. By 1991, survival of about half the selections planted at the Orchard site exceeded 50 percent. By 1993, this number had diminished to 25 percent of the selections initially planted. Annual precipitation received during this 3-year period was well below normal, and accounted for the rapid decline in survival. During this same period, survival of most planted selections remained high at the Nephi site.

Sources of western yarrow with the greatest field performance through 1991 at the Orchard site (Table 3) included collections from Pittsburgh Landing (B39), Brownlee Dam (B 40), and Breadloaf Rock (B41) . All are Idaho collections. Survival of all sources of western yarrow continued to decline through 1995 at the Orchard site, and none now provide acceptable stands. Most selections of this species have persisted well at Nephi and currently maintain vigorous, healthy, dominant stands. Extensive collections of native ecotypes of western yarrow were not assembled and planted, but sufficient differences in survival among ecotypes would confirm that genetic variability regulates adaptation and plant survival. Western yarrow is a widely distributed species with numerous subspecies and confirmed ecotypes. Broader selection and development processes could be used to develop material better adapted to arid locations.

Western yarrow often occurs as an understory species with other herbs and shrubs. Plants normally do not exist as dense solid patches, but occur as small clusters capable of spreading by root proliferation. When transplanted into spaced plantings as in this study, plants tend to permit invasion by other species. This process proceeds more rapidly when plants are under stress as occurred at the Orchard study site. Although some decline or adjustment occurred at the Nephi site, the change was much less obvious. Natural decline in plant density or cover is an important issue as reduction in competition can result in the invasion of annual weeds. By contrast, the decline in understory density can also be important for the natural recruitment of associated native species.

Selections that have persisted at the Orchard site over the 10-year test period have done so in spite of a 4-year period of unusually low water availability. The total test period provides a relatively short time period for evaluating natural recruitment and performance under variable climatic conditions. However, the most successful and persistent species recorded at the Orchard site has been Asiatic yarrow (Achillea asiatica B1, PI 380611) acquired from Iran. This selection has also survived well at the Nephi study site. Nearly all plants that initially established have been able to survive at both locations. Existing plants are healthy and vigorous despite being subjected to very dry conditions at the Orchard study site. The initial group of yarrow species planted in this study were evaluated to define their potential to control cheatgrass (Bromus tectorum) by direct competition and serve as potential candidates for greenstrip plantings. The selection of Asiatic yarrow has been the most successful introduction for controlling annual weeds and serving as a species for fire abatement. Most other sources of yarrow exhibiting good survival have also demonstrated sufficient competitive ability to suppress annual weeds (Table 2); nearly all selections growing at Nephi are free of weeds. At each location, plants were established at 28 inch spacings. For most species, this has been adequate to control weeds even in young plantings, but closer spacings of some selections could be used to better control weeds.

Persistence and longevity of established stands of yarrow species are dependent on natural recruitment from seed or vegetative spread. No attempts were made to weed plots, and natural spread was subjected to considerable competition from weeds, particularly at the Orchard site. Rate of vegetative spread was determined for all plots at both study locations beginning in 1991. At this time, plants had not attained mature status, but some were already proliferating vegetatively. By 1994, plantings of Achillea nobilis and Achillea sulfurea had both spread beyond the original plot borders at Nephi (Table 2); plants of A. sufurea occupied about 90% of their plots; and plants of A. sulfurea were less aggressive, occupying about 60% of their plots.A. sulfurea developed a uniform, open, but dominant stand. Few annual weeds have invaded plots of this species at the Nephi site. Spread by stem rooting occurred at the Orchard site for A. sulfurea, but no other species. Six selections of Western yarrow at Nephi increased crown diameter by rooting from stems. Vegetative spread appears capable of sustaining plant density and vigor of all Western yarrow collections in areas where they are adapted.

Species selection trials were instigated to evaluate the usefulness of yarrow in fire barriers or greenstrip plantings. The principal characteristics considered important for plantings of this type were survival, competitive suppression of annual weeds, flammability, and other features that would influence the spread of fire including plant growth habit, deposition of dry litter, plant spacing, and summer greenness. This information was collected from plantings at both study sites annually. The importance of some burning characteristics were not fully evaluated until large, single species plots were burned in 1997.

Water content of leaves is considered a critical measure of flammability and can be measured with some degree of accuracy. Randomly selected plants of all accessions grown at Nephi were assessed weekly from 28 June 1994 to 1 Sept. 1994 (Table 4). Dry folage increased to 80-85 percent by 27 July. However, at this level plants were sufficiently green to reduce the spread of fire. A. confera (ACCO B1); western yarrow (B28); and (B29) retained more water later in the season than other selections planted.

Although the water content of herbaceous plants is important in controlling fires, the amount and presence of litter, presence of flower stalks, and the arrangement of dry leaves have also been recognized as important features. Initial burning trials of individual plants demonstrated that dry seed stalks and floral heads ignited easily and burned quickly. Fire burning in the dry floral tissue could ignite and cause green leaves to burn. Consequently, species and individual plants with few seed stalks were initially considered best adapted for greenstrip plantings. Some robust selections of Western yarrow tended to produce numerous seed stalks. Thus, plants with aggressive and competitive growth habits were sometimes disregarded as candidates for greenstrip plantings. In 1997, large blocks of yarrow were burned late in the season under dry and windy conditions. Fires were observed to burn through solid plantings of yarrow,.and dry floral tissue was observed to be a principal fuel source. However, open stands with non contiguous arrangements of floral stalks did not carry a fire unless unusually high and consistent winds occurred. Even under these conditions, the presence of dry floral material was not capable of carrying a fire for more than a few meters. Fires usually diminished and subsided quickly. Various species of yarrow maintain sufficient water in the leaves until late summer, decreasing the ignition and movement of fire. Plants remain green later than most perennial grasses and provide a useful fuel barrier.

In addition to summer greenness, the competitive influences of yarrow plantings were evaluated as a means to control cheatgrass. To be effective, greenstrip plantings must be capable of reducing the dry fuel load produced by under story weeds. Most species offer sufficient competition to prevent weed invasion if plants are properly spaced and retain a competitive density. As previously mentioned, some selections of western yarrow do not persist as solid dense stands. As density declines, weeds can invade. All plantings were centered at 28 in spacings. At this spacing young plantings can be invaded by weeds, but as plants mature weed density declines. From evaluations conducted in 1993 and 1994 at the Nephi site, a number of selections of western yarrow and Asiatica yarrow provided the most competition to understory annuals, Table 2.

Based on all factors considered important for greenstrip plantings, including weed control, survival, and fire resistant attributes, a single species emerged as the most feasible candidate of all yarrows tested. The selection of Asiatica yarrow has survived adequately under extremely arid conditions (Table 5). Plants established at 28 in spacings have completely suppressed annual weeds including cheatgrass and bur buttercup (Ranunculus testiculatus). In addition, plants remain sufficiently green during the late summer to prevent burning. Plants spaced from 28-36 inches apart do not overlap and do not provide a contiguous fuel supply. The open interspace do not furnish fuel to carry a fire. This selection appears widely adapted and capable of growing within the drier regions of the Snake River Plain. It appears as the most useful candidate to plant in conjunction with forage kochia (Kochia prostrata) and crested wheatgrass (Agropyron cristatum) to create a fuel barrier or greenstrip. This selection has been established at two field locations to produce seed for large-scale plantings. The decision to nominate this selection as a cultivar release has yet to be determined.

A large project planting has been established at the Mountain Home Military Base, Saylor Creek Bombing Range, to evaluate the combined utility of planting alternate strips of Asiatic yarrow, forage kochia, and crested wheatgrass as a greenstrip. Replicated plots 200 ft x 50 ft in size have been established and controlled burning is scheduled to measure fire spread and fuel characteristics under situations simulating a large wildfire.

The native selection of western yarrow acquired near Eagle, Idaho has been developed and will be released in 1998 as a source identified for restoration of sagebrush communities in southern Idaho. Seed of this selection will be available for commercial production in 1998. Studies have indicated this selection can be established with limited seedbed preparation when seeded in mixtures. The selection is a native forb that can be used in restoration plantings to improve biodiversity and control annual weeds.

An introduced species of Asiatic yarrow has been developed for use in greenstrip plantings. This species has demonstrated adaptability to the arid regions of the Snake River Plain and is highly competitive with annual weeds. It is persistent and maintains summer greenness which restricts the spread of fires. Seed production is generally low, but two cultivated fields are under production in Utah and Idaho to increase field production and provide seed for wildland plantings.

Conclusions

Western yarrow has been widely and successfully used to restore upland communities in aspen park, pinyon-juniper, and sagebrush/steppe communities. It has performed as a useful pioneer species to naturally reoccupy disturbances in these communities and it produces excellent ground cover and wildlife habitat. Current studies indicate some yarrow species and accessions are adapted for use in specific sagebrush communities. Selections of Western yarrow included in these trials were not well adapted to the more arid regions occupied by Wyoming big sagebrush (Artemesia tridentata ssp. wyomingensis) in Southern Idaho. However, a selection from Eagle, Idaho can be recommended for use in the foothill and more mesic regions of the Snake River Plain.

The Eagle, Idaho selection, B37, is an upright, moderately spreading plant. It establishes quickly from broadcast seeding or shallow drilling, thus requiring minimal seedbed preparation. It provides considerable ground cover and competes with weeds during its first growing season. Few other broadleaf herbs establish as rapidly. This selection can be used to restore native communities and is one of only a few species that can be established with a moderate degree of weedy competition. It provides diversity, wildlife habitat, and competition for annual weeds. It is an important understory throughout the sagebrush community where it occurs naturally. It persists and recovers rapidly following burning, providing ground cover on exposed sites. Through further selection, more drought tolerant accessions could likely be developed.

Selections of western yarrow are capable of serving as greenstrip species. They may also be used to suppress and control weeds; they persist in sufficient density to restrict weed invasion and weed seed build-up. Western yarrow plants do produce seed stalks that become flammable when dry. However, earlier concerns that this species would exacerbate burning conditions and contribute to the rapid spread of fires have not been verified. When solid patches of western yarrow are burned, fires do not spread quickly through the foliage and dry stalks very quickly; dry material is not contiguous and fires are not carried from plant to plant.

Asiatic yarrow has demonstrated excellent drought tolerance and persistence in the Wyoming big sagebrush communities of southern Idaho. Plants established in spaced plots have excluded cheatgrass and provided green foliage throughout the summer. Asiatic yarrow exceeds all other yarrow species evaluated for weed control and fire containment. However, seed production is low, increasing costs and decreasing availability. Establishment by direct seeding and natural spread are slow, but individual plants appear quite persistent. A selection of Asiatic yarrow from Iran is being grown under cultivation for seed increase.

Management Implications

A native selection of western yarrow acquired near Eagle, Idaho has been developed and will be released in 1998 as a Selected class of seed for restoration of sagebrush communities in southern Idaho. Seed of this selection will be available for commercial rearing in 1998. Studies have confirmed this selection can be established when seeded in mixtures with limited seedbed preparation. The selection provides a native forb to facilitate restoration, control annual weeds, and provide species diversity. An introduced species of Asiatic yarrow has been developed for use in greenstrip plantings. This species has demonstrated adaptability to the arid regions of the Snake River Plain, and is highly competitive with annual weeds. It persists and maintains summer greenness to restrict the spread of fires. Seed production is generally low limiting seed production, but two cultivated fields are under production in Utah and Idaho to increase field rearing and provide seed for wildland plantings.

Table 1. Yarrow accessions included in 1989 field plantings at Orchard, Idaho and Nephi, Utah.

Species		Accession No.	Plant Introduction Number	Origin
Achillea	millifolium	28-87	439888	USSR
"	"	29-87	439889	"
"	"	30-87	439891	"
"	"	31-87	439892	"
"	"	32-87	439893	"
"	"	33-87	439894	"
"	"	34-87	439895	"
"	"	35-87	439896	"
"	"	36-88	--	West of Malad, ID
"	"	37-88	--	Eagle, ID
"	"	38-88	--	Pittsburg Landing, ID
"	"	39-88	--	Pittsburg Landing, ID
"	"	40-88	--	Brownlee Dam, ID
"	"	41-88	--	Breadloaf Rock, ID
"	"	42-88	--	Thistle, UT
"	"	43-88	--	North of Fairview, UT
"	asiatica	1-87	380611	Iran
"	conferta	1-87	380610	Iran
"	filipendulina	1-87	380604	Iran
"	micrantha	4-87	439885	USSR
"	micrantha	5-87	439886	USSR
"	nobilis	3-87	439897	USSR
"	santolina	1-87	380612	Iran
"	santolina	2-87	380614	Iran
"	sulfurea	1-87	380609	Iran
"	species	3-87	380613	Iran
"	species	4-87	383528	Turkey
"	species	5-87	439898	USSR
"	species	6-87	439899	USSR

Table 2. Percent survival and presence of weeds from plantings established at Nephi, Utah and Orchard, Idaho.

	NEPHI								ORCHARD				
	Percent Survival					Weed Occurance		% Natural Spread	Percent Survival				
Source	1989	1991	1993	1994	1995	‘93	‘94		1989	1991	1993	1994	1995
ACMIL B28-87	89	90	spread	spread	spread	2.7	3.5	79	75	63	32	32	26
ACMIL B29-87	96	94	spread	spread	spread	2.3	3	66	97	61	35	35	4
ACMIL B30-87	97	97	spread	spread	spread	2.7	4.3	45	85	67	39	39	21
ACMIL B31-87	94	91	90	90	89	2.3	3		87	68	39	40	37
ACMIL B32-87	99	99	spread	spread	spread	3.3	5	38	93	40	17	17	5
ACMIL B33-87	93	90	90	90	87	1	1.7		96	89	55	55	45
ACMIL B34-87	98	96	94	91	91	1.3	2		92	87	62	58	42
ACMIL B35-87	96	90	87	85	76	1.3	2		85	80	42	42	28
ACMIL B36-88	94	92	79	78	71	3	5		79	55	7	6	3
ACMIL B37-88	98	98	91	91	86	2	4		85	71	10	10	4
ACMIL B38-88	97	97	97	97	97	1	2.3		74	57	15	9	8
ACMIL B39-88	94	97	97	97	97	1	1.7		94	87	49	49	39
ACMIL B40-88	96	96	96	96	96	1	1.7		90	79	51	50	28
ACMIL B41-88	99	99	94	93	91	1.7	2.3		82	51	4	4	1
ACMIL B42-88	100	100	50	47	44	3	5		68	35	1	1	1
ACMIL B43-88	99	93	71	60	53	4	4		79	10	0		
ACAS B1-87	100	96	96	99	99	1	1.3		83	76	76	76	75
ACCO B1-87	94	96	96	96	96	2.3	3.7		20	23	23	23	23
ACFI B1-87	70	55	45	45	45	3	5		28	28	21	21	19
ACMIC B4-87	100	99	53	3	3	3.3	5		75	8	0		
ACMIC B5-87	99	90	46	0		4			93	22	0		
ACNO B3-87	96	97	spread	spread	spread	2.3	4	61	89	74	17	17	8
ACSA B1-87	94	96	96	96	96	1.7	3		61	55	53	53	47
ACSA B2-87	94	90	90	90	90	1.7	2.7		69	48	44	44	39
ACSU B1-87	94	spread	spread	spread	spread	1.3	2	88	87	90	spread	spread	spread
ACspp B3-87	93	93	93	93	91	2.3	3.7		25	32	32	32	32
ACspp B4-87	91	93	93	90	87	3	5		18	18	17	17	17
ACspp B5-87	97	94	24	19	12	3	5		97	18	5	5	1
ACspp B6-87	96	91	82	85	84	1.7	2.7		79	71	32	28	15

Table 3. Field performance of yarrow accessions at Orchard, ID and Nephi, UT over 3 years. Ratings are based on a scale of 1 to 10, with 10 being superior.

Collection B Number	Origin	Field Performance						Summer Greenness
		Orchard			Nephi			
		89	90	91	89	90	91	Nephi (1991)
	Achillea asiatica							
1-87	Iran	4	6	6	7	7	7	6
	A. conferta							
1-87	Iran	5	6	8*	8	8	9*	9*
	A. micrantha							
5-87	Soviet Union	8	8	3	8	9	8*	8*
	A. millifolium							
29-87	Soviet Union	7	9	4	7	8	6	5
33-87	Soviet Union	8	8	6	7	8	8*	8*
34-87	Soviet Union	7	7	6	8	8	9*	8*
35-87	Soviet Union	6	6	5	7	8	7	8*
36-87	Malad, Idaho	4	6	4	6	7	7	4
37-87	Eagle, Idaho	4	8	6	7	8	8*	7
39-87	Hell's Canyon, Idaho	5	9	7*	7	8	9*	8*
40-87	Brownlee Dam, Idaho	5	8	8*	7	9	8*	7
41-87	Breadloaf Rock, Idaho	4	7	4	8	8	9*	-
42-87	Thistle, Utah	3	5	2	8	8	7	3
	A. santolina							
1-87	Iran	3	4	5	8	9	7	7
	A. sulfurea							
1-87	Iran	5	7	7*	8	8	7	2

* Indicate those accessions that appear to have performed best.

Table 4. Percent of dry plant foliage for 28 accessions of yarrow growing at Nephi in 1994.

Accession No.	Plot Number	6-28	7-6	7-13	7-20	7-27	8-3	8-10	9-1
ACAS B 1-87	1801	33.75	38.75	49	76.5	86.5	92.25	93.75	94
	2002	45.3	50.6	57.6	91.6	95.3	97	97	98.3
	2312	17.6	22	27.3	58.3	75.6	87.6	87.6	88.3
ACCO B 1-87	1906	8.6	26.6	36.6	51.6	71.6	76.6	77.6	81.6
	2010	6.3	8.6	12.3	18.3	20.6	22.6	24.6	27
	2213	6	8.6	11.6	16	18	23	25.6	26.6
ACFI B 1-87	1911	37.6	42.6	65	82.3	88	90	91	96
ACMIC B 4-87	1913	12.5	28.5	45	87.5	89	98	98	98
ACMIL B 28-87	2201	0							
	2012	44.3	47.6	58.3	78.3	89.3	95.6	96	98.3
	2215	15	21	25	36.6	48.3	58.3	63.3	94.6
ACMIL B 29-87	2306	0							
	2112	17.3	23.3	31.6	66.6	78	84.6	89.6	96.6
	2014	26	31.6	41.6	53.3	61.3	75	81.6	94
ACMIL B 30-87	1907	41	49	63.3	83.3	89.3	89.5	90.5	99.5
	2007	18.6	21.6	53.3	85.6	92.3	97	97.5	99
	2310	26.6	38.3	50	61.6	75	83	86.6	98.3
ACMIL B 31-87	1805	48.3	57.6	96	100				
	2204	41.6	56	92.6	100				
	2113	21	27.6	55	100				
ACMIL B 32-87	1908	36.6	43.3	58.3	83.3	90	80	82	85
	2101	27.6	46.3	80	96	99.3	100		
	2311	30	45.6	58.3	73.3	82.3	85	80	95
ACMIL B 33-87	1806	41.6	47.6	94.3	100				
	2212	41.3	61.6	97	100				
	2115	36.6	42.3	65	97.6	100			
ACMIL B 34-87	1915	49.3	56.6	77.6	98.6	100			
	2107	51.6	77.6	98	100				
	2315	48.3	63.3	93.6	100				
ACMIL B 35-87	2303	65	78.6	97.6	100				
	2104	50	70	96	100				
	2013	56	63.3	93.6	100				

Table 4. Continued.

Accession No.	Plot Number	Sampling Dates 6-28	7-6	7-13	7-20	7-27	8-3	8-10	9-1
ACMIL B 36-87	1808	51.6	73.3	95.3	99.3	99	100		
	2102	51.6	71	91	99.3	100			
	2206	68.3	85	98	100				
ACMIL B 37-87	1909	43.6	53	81	95.3	98	99	99	99
	2011	40.3	48.6	71.6	92.6	96.6	98.6	99	99
ACMIL B 38-87	1910	32.6	43.3	87.3	95	97.6	99	99.3	100
	2108	38.3	46	65.6	84.6	93.3	96.3	96.5	98.5
	2209	31.6	40	50	68.3	83.6	94	95	97.6
ACMIL B 39-87	2305	35	46.6	80	97.3	99.6	100		
	2114	31.6	35.6	55	70.6	81.3	92.6	83	89.3
	2015	37	45	58.3	79.3	91.3	98.3	97.5	99
ACMIL B 40-87	1914	50	56.3	68.6	86.3	95	98	99.3	99
	2208	46	59.3	68.6	86.3	95	98	99.3	100
	2111	41.3	46	56.6	77.6	92.3	97.6	98.6	99.6
ACMIL B 41-87	1904	47.6	57.6	92.6	99.3	100			
	2110	52	70	91.3	98	100			
	2211	46.6	66	83.3	96	98.3	99.6	98	100
ACMIL B 42-87	1809	46.6	98	100					
	2106	78.3	94.3	99	100				
	2207	74.3	96.6	99.6	100				
ACMIL B 43-87	1903	61.6	76	94.6	100				
	2308	77.3	85.3	93.3	95	98	99	99	100
	2009	50.3	60	100					
ACNO B 3-87	1803	25	41.6	46.6	73.3	86	91	93.6	100
	2006	31	45	60	90.6	98	100		
ACSA B 1-87	1807	17	27.6	50	76.6	90.3	100		
	2005	17	23.3	31	55	71.6	90.3	94.3	99.6
	2205	22	31	42.3	63.3	85	92	93	99.3
ACSA B 2-87	1902	14	21.6	35	88.3	97.6	100		
	2307	22	35.3	51	76.6	92	96.6	98	100
	2008	29	38.3	53.3	81	92.6	100		
ACSPP B3-87	1912	21	24.6	31.6	50.6	72.6	84	86.3	90
	2302	18	22	35	65	80	98	100	
		26.5	30	47.5	57.5	67.5	77.5	77.5	77.5
	2109	18	24	35	55	80	98	98	100
		19.5	25	38.5	62.5	74	82.5	85	89

Table 4. Continued.

Accession No.	Plot				Sampling Dates				
	Number	6-28	7-6	7-13	7-20	7-27	8-3	8-10	9-1
ACSPP B 4-87	1810	4	7	11.6	17.6	20	22	23.3	25.3
	2103	4	5	8.6	10.6	12.6	16	17	18.6
	2313	6	8	10.6	13	15.6	17.6	18.6	20.6
ACSPP B 5-87	1901	0							
	2001	22.6	33.3	43.3	92.6	98	100		
	2304	51.6	63.3	73.3	92.3	96.3	99	99	100
ACSPP B 6-87	1802	36.6	52.6	97.3	100				
	2210	89	98.3	100					
	2214	60	92.6	99	100				
ACSU B 1-87	1905	94.3	98.6	100					
	2004	95	98	99.3	100				
	2309	94.3	97.3	99.6	100				

Table 5 -- Features of select species and sources of yarrow.

Sources	plant height	longevity	veg. spread	flower color	seed prod.	seedling establ.	fire tolerance	summer greenness	weed suppression	survival	
										Nephi	Orchard
ACMIL 28, 29, 30, 32 ACNO USSR	mod.	long-lived	rapid	white	fair	unk	excellent	fair	poor	fair	poor
ACMIL 31, 33, 34, 35 USSR	mod +	long-lived	mod	white	good	unk	excellent	good	fair to good	good	fair
ACMIL 36, 41 ID	mod +	long-lived	mod	white	good	unk	excellent	fair	fair to poor	good	1 poor
ACMIL 37 Eagle, ID release germplasm	mod +	long-lived	mod	white	good	good	excellent	fair	fair	good	poor 4%
ACMIL 38, 39, 40 ID	mod +	long-lived	mod	white	good	unk	excellent	good	good	excellent	8,39,28 fair
ACMIL 42, 43 UT	mod	long-lived	rapid	white	good	unk	excellent	poor	poor	44, 53 fair	1.0 poor
ACAS Iran	short	long-lived	slow (layering)	yellow	poor	unk	good	good	excellent	99 excellent	75 excellent
ACSA Iran	mod	long-lived	none	yellow	fair	unk	unk	good	fair to good	96 90 excellent	47-39 good
ACMIC USSR	mod	short-lived	none	yellow	fair	fair	good	good	poor	?	?
ACSU Iran	short	long-lived	rapid +	yellow	fair	unk	excellent	poor	good	100 excellent	100 good
ACCO Iran	Tall	long-lived	none	yellow	fair	unk	good	good	fair -	96 excellent	23 good

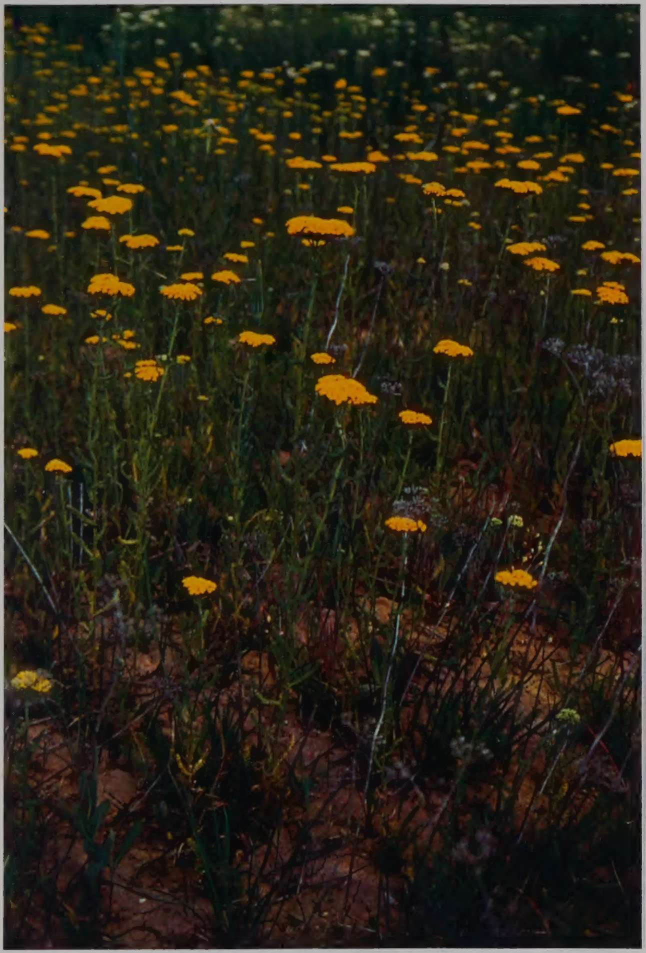

Figure 1. ACSU B1-87 Nephi, Utah.

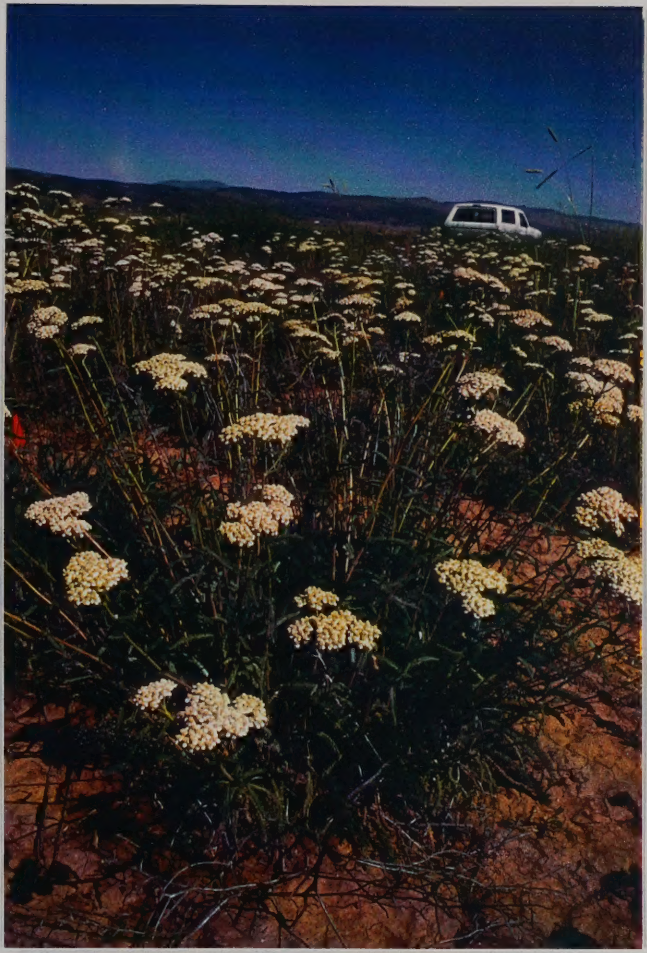

Figure 2. ACMIL B39-88 Nephi, Utah.

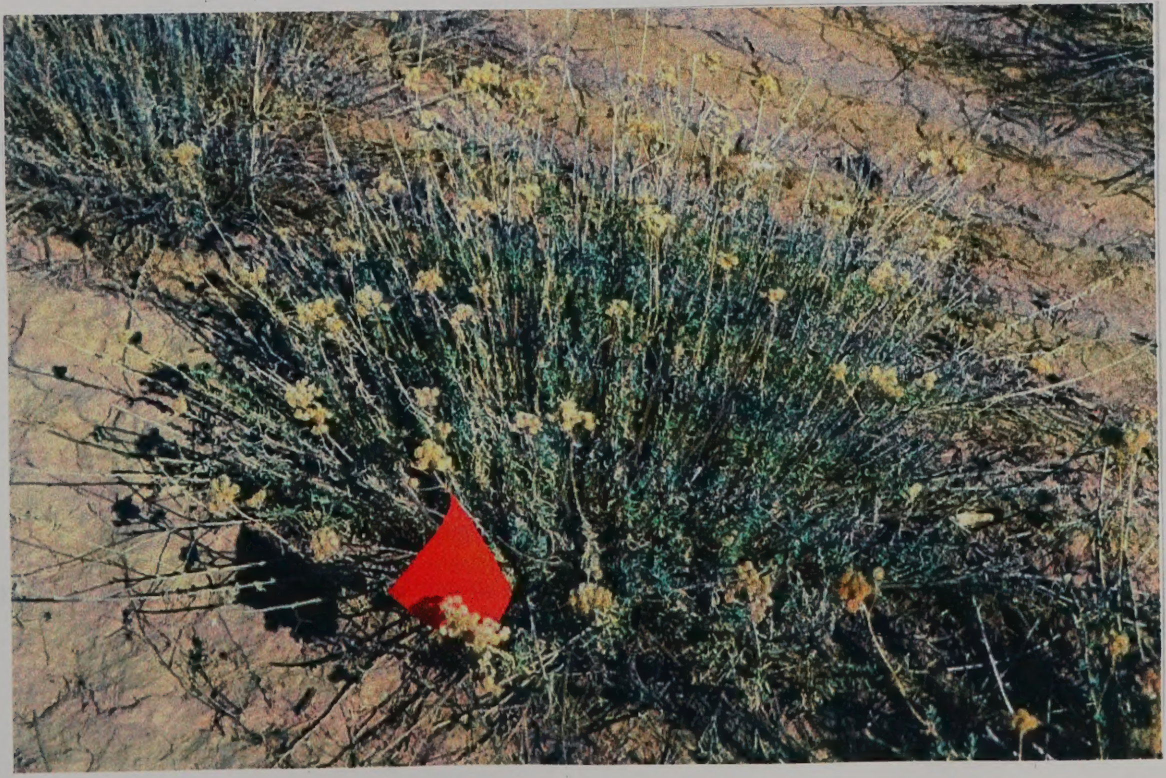

Figure 3. ACSA B1-87 Nephi, Utah.

Seed Germination and Seedling Establishment for Penstemon, Perennial blue flax, and Arrowleaf Balsamroot on Intermountain Rangelands

Stanley G. Kitchen and Stephen B. Monsen

Introduction

Perennial forbs are important components of semi-arid rangelands in western North America. They often account for a large fraction of species richness, even when their contribution to total biomass is relatively small. Vegetation, flowers, and seeds are used for food by many species of wildlife often during periods of time when grasses offer only low quality forage. In addition, perennial forbs provide critical food and habitat for a variety of invertebrates who, in turn, support bird populations.

With a few exceptions, perennial forb establishment from revegetation and restoration seedings has not equaled that of perennial grasses. Perennial forb seedlings are generally slower to establish than are grass seedlings and do not do well when seeded in close proximity to more competitive species. Also, the seeds of many forbs are dormant at seed maturation. This dormancy functions to regulate the timing of germination to episodes associated with reduced risk and, for some species, to insure that a soil seed bank is maintained. An understanding of germination patterns and seed dormancy for perennial forbs is fundamental if they are to be successfully included in efforts to reclaim or improve semi-arid rangelands.

Objectives

Our objective was to evaluate, under laboratory conditions, seed dormancy and germination patterns for several perennial forb species adapted to semi-arid conditions encountered in the Intermountain west. For several species, field retrieval and/or emergence trials were also conducted, enabling us to compare laboratory and field results. Finally, we are developing recommendations for managing seedings that include perennial forbs to increase initial establishment and long term persistence.

Methods

Here we give only a general overview of methods used in several studies associated with the genus *Penstemon*, perennial blue flax (Linum perenne, *L.* lewisii), and arrowleaf balsamroot (Balsamorhiza sagittata). More specific detail is available in the six published manuscripts listed in the **Technology Transfer Products** section of this paper. Penstemon and flax studies were completed in cooperation with Dr. Susan E. Meyer, a Forest Service Ecologist at the Shrub Sciences Laboratory.

Seeds were collected from numerous representative populations for each species or group of species to be studied. The value of these studies was greatly enhanced by including a geographically and elevationally broad range of sites. Seeds were cleaned and stored dry until tests were initiated. Replicated germination experiments were designed to determine seed germination responses to light, incubation temperature, prechill (cold stratification), and prewarm (warm stratification) under controlled laboratory conditions. For some species, seed subsamples were buried at study sites in mesh bags. Bags were retrieved periodically and seeds were inspected for germination status. Ungerminated seeds were then tested under controlled conditions for germinability and viability.

In second level studies, seeds were collected from individual plants within common gardens. Germination patterns among collections and among individuals within collections were compared to determine heritability of germination and dormancy traits. Results were also compared to those of seeds taken from naturally occurring populations.

A third kind of study involved seeding a known quantity of seeds in replicated plots at various study sites. Plots were monitored during the spring for initial emergence and periodically thereafter for emergence and survival. Results of retrieval and emergence studies were compared to those of the controlled germination experiments. Interpretation was aided by reviewing climatic data for the site.

Results and Discussion

A brief description of results are discussed here on a species or genus group basis. More detailed examination of results and interpretations are available in the manuscripts listed in the **Technology Transfer Products** section of this paper.

Penstemon--We found seed dormancy and germination requirements varied greatly among and within Intermountain species of the genus *Penstemon*. Long chilling requirements (16-24 weeks), non-chill responsive seed fraction, cold-induced secondary dormancy, and light requirement all function to preserve a persistent seed bank. High levels of primary dormancy were the rule, especially for northern collections. Mid-elevation collections were generally the most conservative, suggesting that conditions in these environments are highly variable and more unpredictable than those of either lower or higher altitude. Results of experiments using seeds collected from common gardens suggest that among-population and among-plant (within-population) differences in germination pattern have a strong genetic basis. Care should be made so that, as species are brought into cultivation, inadvertent or purposeful selection for agronomic convenience does not result in the loss of this genetic diversity (Meyer and Kitchen 1995).

Linum--Perennial flax collections from six western states were compared to the cultivar, 'Appar'. Although released as a native, 'Appar' is now recognized as belonging to a European species distinct from North American material (Pendleton and others 1993). In our study with native perennial flax collections primary dormancy varied considerably. Response to prechill also varied. Seed collections from sites with significant dependable snowfall had generally high levels of post-harvest dormancy and responded positively to chilling. Collections from middle elevation sagebrush/grassland sites had low to moderate post-harvest dormancy and either had no response or a negative response to chilling. Populations from the pinyon/juniper and palouse prairie sites had low initial dormancy and generally were not affected by chilling. Seed in retrieval experiments responded as predicted from laboratory experiments. Germination responses from seeds harvested from common gardens suggested differences among and within populations are genetically based. 'Appar' seeds were not dormant nor responsive to chilling and appear less capable of maintaining a persistent soil seed bank than do the native collections. These traits may have been selected for through cultivation practices.

Balsamorhiza sagittata--Arrowleaf balsamroot seeds are dormant at harvest. Seeds responded to laboratory prechill treatments of 4 to 12 weeks. After-ripened seeds required less prechill than recently-harvested seeds. Seeds that experienced summer soil conditions (retrieval experiment) were less responsive to prechill by fall than were laboratory stored seeds. By early spring, seed dormancy was broken and emergence was limited only by crusting of the soil surface. We found no evidence that arrowleaf balsamroot maintains a persistent seed bank. Seedlings grew slowly and experienced a relatively low rate of mortality on sites suited for this species.

Management Implications

Managers seeding native forbs in revegetation or restoration projects need to be knowledgeable of germination patterns and seedling growth rates, life history strategies, and competitive attributes of perennial forb species being planted (Kitchen 1994). Site conditions should be matched to appropriate ecotypes. This will not only insure proper germination timing and emergence, but also that the population will have a reasonable opportunity to persist. When seeding species or ecotypes known to have high levels of seeds that are dormant and not responsive to chilling, seeding rates should be increased to improve the likelihood of successful stand establishment. Site preparation and seeding practices should be adopted to minimize competition for seeded forbs from weeds and seeded grasses.

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Technology Transfer Products

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Plant Materials--

Seeding trials in greenhouse experiments and on three rangeland sites revealed that seedling emergence and survival for several native flax collections was equal to that of 'Appar'. Native collections of perennial flax were compared for seed germination, seedling emergence success and growth rate, seed production, rust resistance, longevity, and drought tolerance. Based on these results, a collection from central Utah (Maple Grove) was selected for further development and release. A seed increase garden has been established in Ephraim, Utah in anticipation of the planned source identified, selected class, release of this collection. This source appears to be well adapted for seedings on sagebrush/bunchgrass, pinyon/juniper, and mountain brush communities receiving 300 to 400 mm mean annual precipitation.

Small Burnet

Scott C. Walker and Kyle D. Moore

Problem

In the revegetation of rangelands there is a need for perennial forbs that are nutritious, have good growth characteristics and provide succulent forage. Many of the species seeded in range revegetation projects become dry or dormant for a period of time throughout the summer heat, and during winter months.

Small burnet (Sanguisorba minor Scop. Rosaceae) is an introduced, perennial evergreen, cool season, rosacious forb, native to Eurasia. Several species of burnet now grown in the western United States come from Mediterranean and Middle Eastern countries as well as the USSR (Fisher et al. 1978). These species have adapted to the Intermountain West where they are used as forage by domestic livestock, wildlife, and by man as medicinal plants (Mukhametshina et al. 1989).

Small burnet has many desirable characteristics that make it an important species used in range reclamation; such as, high nutrition, drought tolerance, evergreen, highly palatable, good seedling vigor, and good germination characteristics. This forb remains succulent throughout the growing season and provides nutritional forage through the winter months. Small burnet has been successfully used in rehabilitation efforts of degraded sites throughout the Intermountain Region (Shaw and Monsen 1983). Success of small burnet is due, in part, to years of establishment, good winter hardiness and moderate fire and shade tolerance.

Growth of small burnet is initiated in early spring, in general seedling growth and vigor are excellent (Autenrieth et al. 1982). Flowering occurs in May or June, and seed matures by late August to early September. Pollination is done primarily by insects. Large amounts of seed and foliage are often produced in the first growing season. The percentage of seeds planted that later emerge as seedlings to become mature plants, is higher (5 to 8%) for small burnet than for almost any other species commonly seeded, with seed germination at 80 to 90%. This species contains nearly 55,000 seeds per pound (121,000/kg) at 100% purity. Commercial seed lots are at least 90% pure and exhibit

95% germination. Seed will remain viable without a substantial loss in germination for up to 15 years in a warehouse setting (Stevens et al. 1981).

In the Intermountain Region, stands can be successfully attained by fall and in early spring seedings (Stevens and Monsen 1994). Seeding in the Northern Great Plains and Midwest is optimally accomplished in late fall. Seedings within mountainous areas are also most successful when planted in the late fall. If irrigation is utilized, seeds will germinate and grow when seeded anytime from early spring to July or mid August. Small burnet can also be propagated from crown divisions (Robertson 1974).

Within the Intermountain region "Delar", an accession of small burnet, has been selected and commercially released because of superior seedling vigor, high growth rates, and good forage production (Plummer 1977). Small burnet also has good drought tolerance and is quite adaptive to a wide range of growing conditions. The species is usually fire-resistance due to its succulent, and evergreen leaves (Howard 1978). Delar has been shown to survive on sites with less than 12 inches (30.5 cm) annual precipitation. It can grow on soils with pH values of 8.0, and survives winter temperatures as low as -33 F (-36 C). Delar is not well adapted to poorly drained soils with high water tables (Plummer et al. 1968, and Vallentine 1971).

Livestock, big game, rodents and upland game birds show high preference for small burnet year-round (Autenrieth et al. 1982, and Wasser 1982). Small burnet is especially important in late winter, early spring, and late summer when most other species show little or no green forage. Continuous grazing at these critical time periods have been shown to reduce stand vigor and density of small burnet (Vallentine 1971). Small mammals often forage on the seed of small burnet. Small burnet is a prolific seed producer and can provide a high amount of nutritious forage for seed eaters. However, if large amounts of seed are consumed by rodents, it may severely reduce natural population increases. Where rodent populations are moderate to low, successful reproduction of small burnet will occur (Everett et al. 1978).

Small burnet is a frequently planted forage species worldwide. It is commonly recommended in seed mixtures used to revegetate rangelands, game range restoration, mine spoils and other disturbed areas. In Utah, small burnet is one of the most commonly seeded forbs used for range restoration projects in juniper- piñyon, mountain brush, aspen, black brush, big sagebrush, shadscale, and saltbush types (Stevens and Monsen 1994).

Stevens and Monsen (1994) examined a number of small burnet accessions planted on a site in southern Idaho southeast of Hagerman (T. 7 S., R. 12 E., Sec. 35 & 36) that receives 7 to 9 inches (17.8 to 22.9 cm) of precipitation annually. Five of these accessions persisted for over 10 years, and included two accessions from the USSR (B28 and B34), and one each from Yugoslavia (B10), Spain (B30), and Iran (B51). Though the commercial release "Delar" has many good characteristics, the survival characteristics of these accessions demonstrated that there is potential for a more drought tolerant accession than the commercial release of "Delar".

Methods

Studies were designed to evaluate the drought tolerance of these aforementioned five accessions and the commercial release "Delar". Two field plantings were established in central Utah to evaluate these six accessions in a common garden situation. The sites were located at the Nephi Field Station in Nephi, Utah, and the other site was located at the Great Basin Research Center, Snow Field Experimental Station at Ephraim, Utah. Annual precipitation for the two sites were adequate for good plant growth at 14 to 16 inches (35.5 to 40.6 cm) at Nephi, and 8 to 12 inches (20.3 to 30.5 cm) at the Ephraim site. Separate studies were initiated beginning in 1992. Variables studied included drought tolerance, nutritive quality, plant production, and seed germination characteristics (Moore 1995).

Drought tolerance was examined by measuring the plants pre-dawn water stress with a pressure chamber (Nobel and Jordan 1986, Brown and McDonough 1977, and Slatyer 1967). Monthly (May to September) leaf moisture stress was taken on the six accessions of small burnet (Moore 1995). A second study designed to measure drought tolerance was completed. This second study evaluated plant response to water stress by measuring metabolic heat rate and respiratory rate. This study not only looked at these same six accessions of small burnet, but also compared these small burnet samples to different varieties of dry land alfalfa (Medicago sativa)(Jones et al. 1998). Nutritional values of each accessions foliage were determined throughout the growing season of

1994. Tissue samples for the nutrition measurements were taken on the same dates as the pressure chamber data. Sample were air-dried, ground and subjected to near infrared reflectance spectroscopy (NRI) for nutritional analysis. Compounds reported include: protein, phosphorous, calcium, potassium, magnesium, digestible dry matter (DDM), total digestible nutrients (TDN), and metabolizable energy (ME).

Above ground biomass production was collected at the end of the 1994 growing season. Three plants from each accession were sampled. Each plant was harvested by clipping at ground level, then weighed, air-dried, and re-weighed for the mean net biomass production.

Germination, and seedling emergence and vigor, among small burnet accessions with respect to seed size were investigated. "Delar" accession seeds are larger and are hypothesized to germinate more efficiently than do those of the other Eurasian accessions. The objectives of these studies were to determine differences of which accession produces seed with the best overall germination biology, and emergence capacities from four planting depths.

In mid-August of 1992, seeds were collected from each accession at the Nephi site. The seeds of each accession were cleaned separately. The seeds of each accession was separated into four different size classes using a series of screens. The four seed size classes were: 1) larger than 10/64 inch (4 mm) mesh screen opening; 2) smaller than 10/64 inch (4 mm), but larger than 8/64 inch (3.2 mm); 3) smaller than 8/64 inch (3.2 mm), but larger than 1/12 inch (2.2 mm); and 4) smaller than 1/12 inch (2.2 mm) mesh screen opening. Some accessions had seed in all seed size classes, others did not. Seed from each size class in each accession were sampled to test for fill or fully developed embryos. This test demonstrated the number of compartmented achene chambers filled with embryos (1, 2, or empty).

Germination tests were completed on each size class for each of the six accessions. Two treatments were used, a continuous warm temperature of 68 to 70 F (20 to 21.1 C) and a continuous cold treatment of 36 to 38 F (2.2 to 3.3 C).

Seedling emergence was evaluated by a replicated study of planting seed from each seed size for each accession at four planting depths. Seedling vigor was evaluated on numbers of seedlings emerging and survival of seedlings from depths of 3 inches (76.2 mm), 2 inches (50.8 mm), 1 inch (25.4 mm), and 0.5 inch (12.6 mm). Planting medium was washed sand that was contained within boxes 24 inch (61 cm) x 24 inch x 10 inch (25 cm). The study was carried out in a green house where temperature was controlled, and moisture was not limiting.

Data were subjected to analysis of variance and mean separations using Student-Neuman-Kuels statistical method ($p<0.05$).

Results and Discussion

Pressure chamber results showed a significant difference between the water stress potential between the six accessions. The data indicate that the commercial release "Delar" (U13) is not the most drought tolerant of the accessions considered. Accessions B10, B28 and B51 exhibit more tolerance to lack of water in the soil than the other three accessions B34, "Delar", and B30.

Results of measurements of metabolic heat rate and respiratory rate showed both small burnet and alfalfa grow best in early spring but remained green and active throughout the summer. In general the small burnet accessions studied were more drought tolerant than the dry land alfalfas (Jones et al. 1998).

Mean nutritional analysis varied with respect to nutrient category and with each accession throughout the growing season (Table 1). "Delar" had the highest protein, mineral levels, as well as the highest levels of digestible nutrients and metabolizable energy of any of the accessions analyzed.

Above ground biomass production showed on average that accession B51 produces more biomass than any of the other accessions (Table 2). "Delar" produced the second highest biomass production among all accessions examined.

Seed size varied for the accession. Seed of "Delar" had the highest weight per seed, averaging 99 seeds per gram (35 seeds per oz). Very similar to "Delar", B10 had on average 100 seeds per gram (35 per oz). B28 averaged 163 seeds per gram (58 per oz). B30 averaged 213 seeds per gram (75 per oz). B34 averaged 233 seeds per gram. Finally B51 averaged the smallest seed at 238 seeds per gram (84 per oz), nearly two and a half times as many seeds per gram as the largest two accessions.

Accessions within this study did not have an even distribution of seed size classes among all accessions. The larger the seed size the class, the more likely the seed was to successfully germinate; conversely, the smaller the seed size class, the less likely the seed was to germinate (Table 3).

The mean germination for all accessions and all seed sizes within the cold treatment was 81% and 93% for the warm treatment. It is noteworthy that small burnet appears to be a species that has adapted efficiently to warm season germination as well as cold season germination.

These studies indicate there are differences in germination, growth, nutrition and drought tolerance between accessions of small burnet. B51 shows good growth and drought tolerance even though it has the smallest seed. "Delar" has extremely good germination and seedling emergence yet may not be the most drought tolerant. However, it is important to point out that even within an accession there is seed size differences. These differences allow for small burnets wide range of adaptation to different climatic scenarios.

Interspecific differences within the accessions of small burnet may reflect the genetic strategies needed to be able to buffer against fluctuations in an ever changing environment. Species like small burnet as a seed species are of great value in areas within the Intermountain Region, especially in many grass and grass-forb combination seedings.

Management Implications

Small burnet has unequal success along an elevational gradient. Welch et al. (1993) indicates that at least in Utah small burnet will be successful between 1525-2135 m elevation. Nonetheless, small burnet grows well in lowland gardens and often is included in high elevational seedings in the Rocky Mountains.

Small burnet is sensitive to herbicides and further studies are needed for their safe use around the species. The species has attractive evergreen leaves, color, and interesting foliage and produces cover and food useful to a variety of animals. Small burnet increases biodiversity of the local plant community as well as enhances nutritional quality and seasonal availability of green herbage in most Intermountain vegetational communities. It is a compatible component in grass, grass legume, or more complex seed mixtures.

Optimal vegetation management for this species will require that not more than 50% of its living tissue be removed by grazing and that it not be grazed continuously for long periods. The species should receive periodic rest from grazing to encourage self seeding and ensure stand longevity (Stevens 1993). Most individuals of the species have an average life span of 7-12 years, however some have persisted for up to 20 years (Plummer et al. 1968, Stevens et al. 1977).

Aerial or hand broadcasting, drilling or dribbling during fall or winter have produced good stands of small burnet in Central Utah (Stevens and Monsen 1994). Dryland areas need to be seeded before the arrival of fall moisture to ensure rapid germination and establishment.

In the Intermountain Region, seeding is recommended in early spring (Stevens and Monsen 1994). Seeding in the Northern Great Plains and Midwest is optimally accomplished in late fall. Mountainous areas do best when seeded in late fall or early to mid summer. If irrigation is utilized, seeds will germinate and grow from early spring to July or mid August. Small burnet can also be propagated from crown divisions.

Recommended seed rates are about 20 to 30 live seeds per square foot (20 to 30 PLS per acre) to produce a full stand (Howard 1978). Use of small burnet in seed mixes is advised at 1 to 3 pounds PLS per acre.

Sites that are disturbed, harsh or degraded may be seeded with increases of 50 to 100 percent. Flourishing establishment in these areas may be increased by mulching, irrigation, and fertilization (Howard 1978).

Seeds must be covered when drilling. Drill seed at 1/4 inch (6mm) but never exceed 3/4 of an inch. As always, adjustments must be made on soil texture, moisture, and compactness. The general rule is to seed slightly deeper in the fall than spring (Plummer et al. 1968).

Small burnet is a frequently planted forage species world-wide. Domestic and wildlife animals use it because it has excellent forage and seed production (Fisher et al. 1987). Man's uses of this species are numerous and increasing as research generates new knowledge about the species.

The ease of seed processing, ease of planting, reliable seedling establishment, and the overall longevity of small burnet make it a successful revegetation species in the United States. Use of small burnet is on the increase, since it is a valuable species that could be included in seed mixes used at many locations on this continent. The species is especially useful for use in seed mixtures designed for rehabilitation of degraded rangelands worldwide (Monsen 1994).

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Table 1. Composite nutritional analysis (in percent by content) of the six different accessions of small burnet (Sanguisorba minor Scop.) during the months of May to August, 1994.

Nutrient	B10	B28	B30	B34	B51	U13	Mean	SD
Protein	9.8	13	11.5	12.4	12.2	17.1	12.7	2.4
Phosphorus	0.25	0.27	0.26	0.27	0.27	0.31	0.27	0.02
Calcium	0.97	1.05	0.99	1.21	0.99	1.09	1.05	0.09
Potassium	2.1	2.3	2.13	2.02	2.19	2.58	2.22	0.2
Magnesium	0.26	0.27	0.26	0.33	0.26	0.28	0.28	0.03
DDM[1]	53.27	57.18	56.26	57.61	57.7	63.02	57.47	3.2
TDN[2]	48.1	51.87	50.5	51.43	51.45	57.23	51.76	3.4
ME[3]	1.74	1.88	1.82	1.86	1.86	2.07	1.87	0.11

[1] Digestible Dry Matter
[2] Total Digestible Nutrients
[3] Metabolizable Energy

Table 2. First year above ground biomass production(in grams) for all six Eurasian accessions of small burnet (Sanguisorba minor Scop.).

Accession	REP1	REP2	REP3	Mean
B10	14	50	50	38$_{a}$
B28	41	28	102	57$_{b}$•
B30	30	92	53	58$_{b}$
B34	23	55	91	56$_{b}$
B51	84	71	133	96$_{c}$
U13	60	87	112	87$_{c}$

•means with the same letter are not significantly different.

Table 3. Mean seedling emergence among all accessions, seed sizes, and planting depths.

		Seed Emergence(%) at Treatment Depth (mm)				
Accession	Seed size(mm)	12.6mm	25.4mm	50.8mm	76.2mm	Mean
B10	3.2	55	45	31	2	
B10	2.2	72	60	20	0	36B*
	Mean	63$_a$	52$_a$	25$_b$	1$_c$	
B28	2.2	35	30	11	2	
B28	<2.2	43	16	2	0	17C
	Mean	39$_a$	22$_a$	7$_b$	1$_b$	
B30	3.2	72	56	11	2	
B30	2.2	81	55	17	10	
B30	<2.2	32	15	3	3	30B
	Mean	62$_a$	42$_b$	10$_c$	5$_c$	
B34	3.2	86	61	14	0	
B34	2.2	70	40	5	2	35B
	Mean	79$_a$	51$_b$	10$_c$	1$_d$	
B51	3.2	33	24	4	0	
B51	2.2	54	54	0	0	
B51	<2.2	44	24	0	2	20C
	Mean	44$_a$	34$_a$	1$_b$	1$_b$	
U13	4.0	98	75	56	14	
U13	3.2	97	73	33	17	57A
	Mean	97$_a$	74$_b$	45$_c$	13$_d$	

*column and row means with the same letter are not significantly different ($p<0.05$)

Calorimetric Study of the Effects of Water and Temperature on the Respiration and Growth of Small Burnet and Alfalfa

Angela R. Jones, Bruce N. Smith, Lee D. Hansen,
Stephen B. Monsen, and Richard Stevens

Introduction

Desert plants have adapted to dry climates, but differ in the degree of adaptation among species and cultivars or populations. Plants that better tolerate conditions of low water and high temperature stay green longer into a hot summer, and can be used effectively in green belts and forage projects. Small burnet (Sanguisorba minor) and alfalfa (Medicago sativa) are two such species that grow in the Great Basin. Small burnet is a perennial recently introduced from Eurasia into Utah for erosion control at altitudes between 1525 and 2135 m (Welsh and others 1987). Alfalfa was also introduced from the Old World, possibly into California by the Spanish, and is now one of the most important forage crops in the United States (Stechman 1986; Welsh and others 1987). Both species are tolerant of heat and drought, making them candidates for green belts and forage projects in dry areas, but each species has different cultivars or populations that differ in their degrees of tolerance to drought and heat.

Calorimetry can be used to rapidly evaluate the tolerance limits of a cultivar, accession, or species because it can quantitate the stress response of metabolism. Hansen and others (1994) have shown that simultaneous measurements of metabolic heat rate (q) and respiratory CO_2 rate (R_{CO2}) can be used to calculate growth rate and substrate carbon conversion efficiency as a function of conditions. Predictions about relative fitness can be made by comparing the growth rates and efficiencies of different plants at specific conditions. Plants can then be selected to match environmental conditions at specific sites. Calorimetry offers advantages over traditional field studies by saving time and providing insight into the mechanism of the stress response.

In the model developed by Hansen and others (1994), the specific growth rate is defined as:

Equation 1: $R_{SG} = -[q + R_{CO2}(1 - \gamma_p/4)\Delta H_{O2}]/\Delta H_B$

where γ_p is the average oxidation state of the substrate carbon, ΔH_{O2} is a thermodynamic constant equal to -455 kJ mol^{-1} O_2 and ΔH_B is the total enthalpy change associated with the conversion of one mole of substrate carbon into one mole of biomass carbon. Assuming that γ_p is equal to 0 (i.e. that carbohydrate is the substrate) and that ΔH_B is a constant, the relative specific growth rate ($R_{SG}\Delta H_B$) can be calculated from measurements of q and R_{CO2}. When q and R_{CO2} are measured as functions of environmental variables, growth rate can then be calculated as a function of the same variables.

The substrate carbon conversion efficiency (ϵ) can be calculated from the same parameters used to calculate the relative specific growth rate. The ratio of metabolic heat rate to respiratory CO_2 rate (q/R_{CO2}) is an indicator of substrate carbon conversion efficiency.

Equation 2: $q/R_{CO2} = 455(1 - \gamma_p/4) - [(\epsilon/(1 - \epsilon)]\Delta H_B$

Substrate carbon conversion efficiency (ϵ) ranges from 0 to <1. Values of q/R_{CO2} are typically between 300 and 450 kJ mol^{-1}. In this range a lower value of q/R_{CO2} may indicate a higher efficiency although changes in γ_p and/or ΔH_B can also affect the ratio. Under conditions where the substrate being burned in respiration is carbohydrate ($\gamma_p = 0$), and ΔH_B is endothermic, i.e. positive, the value of q/R_{CO2} cannot exceed 455 kJ mol^{-1}, but the value of q/R_{CO2} is often observed to exceed 455 kJ mol^{-1}. If q/R_{CO2}>455 kJ mol^{-1}, either the substrate being burned is no longer carbohydrate (i.e., γ_p has changed to a positive value), or the biomass being produced has changed (i.e., ΔH_B has changed to a negative value), or both. Either option indicates that a change in the biochemical pathways has occurred, either the substrate being burned has changed, or the product biomass composition has changed.

Arrhenius plots of metabolic heat rate versus reciprocal absolute temperature (ln(q) vs, T^{-1}) can be used to describe the temperature dependance of q over a temperature range. The temperature coefficient, μ_q, is obtained from the slope of the Arrhenius plot. Likewise, the temperature coefficient of the respiratory CO_2 rate, μ_{CO2}, is the slope of the Arrhenius plot of the respiration rate versus reciprocal temperature ($\ln(R_{CO2})$ vs. T^{-1}). μ_q and μ_{CO2} provide physiological data on the effect of temperature on the metabolism. Differences in the temperature dependancy of q and R_{CO2} can be used to predict the effects of temperature on the growth of different populations or cultivars.

The purpose of this study is to use respiratory heat and CO_2 rates to select the most drought and heat tolerant populations of small burnet and cultivars of alfalfa. Criddle and others (1997) have shown that calorimetry can be used to rapidly measure metabolic heat rate and respiration rate at different temperatures.

Methods

Field Experiment

Six populations of small burnet were grown in two common gardens maintained by the Utah Division of Natural Resources near Ephraim and Nephi, UT. The variety U13 or Delar is commercially released while the others were grown from imported seed (Moore 1995): B10 (Yugoslavia), B28 (U.S.S.R.), B30 (Spain), B34 (U.S.S.R.) and B51 (Iran). Five cultivars of alfalfa - Henry Mt., Nomad, Ranger, Spreader II, and Ladak 65 - were grown in plots in the garden at Ephraim, UT. Plants in the common gardens grew on shallow limestone soils and were not irrigated. One cultivar of alfalfa, Magnum, was grown .8 km from the Ephraim common garden in deep soils and was irrigated and fertilized. Magnum plants were three years old and were Medicago sativa, the others were two years old and were hybrids of Medicago sativa and Medicago falcata.

Young leaf tissue from small burnet was collected once a week between April 2 and August 7, 1997, and between April 29 and July 10, 1997 for alfalfa. Samples were kept in an ice chest or refrigerated until measurements were made.

Laboratory Experiment

Seeds from five of the populations of small burnet, B10, B28, B30, B34, and B51, and seven cultivars of alfalfa, Henry Mt., Nomad, Ranger, Spreader II, Ladak 65, Magnum, and Yellowhead, were planted in sandy loam on laboratory growth carts. Plants were grown with a 13/11 hour light/dark schedule at a constant 21 °C. At approximately 60 days, plants were subjected to three different watering regimes. Plants were watered to field capacity, 2/3 field capacity, and 1/3 field capacity. Metabolic heat rates and respiratory CO_2 rates were measured between 70 and 77 days. Measurements were taken on two plants from each treatment.

Calorimetry

Metabolic heat rate and respiratory CO_2 rate were measured with a Hart Scientific model 7707 Differential Scanning Calorimeter operated in isothermal mode (Criddle and others 1997). Approximately 100 mg fresh weight of young leaf tissue was used for each measurement. Respiratory CO_2 rates were determined using the method described in Criddle and others (1997). After measurement of metabolic heat rate, a small vial with 40 μl of 0.4 M NaOH was placed into the calorimeter ampule with the tissue. As the CO_2 and NaOH react in solution, heat is produced and the increase in heat rate is proportional to the rate of CO_2 evolution. The heat of reaction for carbonate formation (-108.5 kJ mol^{-1}) was used to convert the heat rate into the rate of CO_2 evolution.

Results

Small burnet

Table 1 lists the flowering and growth data for field-grown small burnet. U13 and B34 had flowering stems and red flowers the earliest (May 13) followed by B30 and B51 which had flowering stems and red flowers on May 19, and then B10 and B28 which had flowering stems on May 19 and red flowers on May 27. U13 had the slowest growth while B10 and B34 have slow growth early in the season, but growth increases in June. B28, B30, and B51 show the greatest production, with B51 showing the greatest growth early, maintaining good growth longer.

Both small burnet and alfalfa grow well early in the spring. During the first portion of the growing season, respiration rate (R_{CO2}) and efficiency (ϵ) are high, that is, q/R_{CO2} is low (table 2). There were no significant differences in respiratory properties between the populations of small burnet grown in Nephi and those grown in Ephraim. Also, the q and R_{CO2} values obtained did not change with sampling date except a few days following flower maturation. Therefore all data before and after this ontological event were averaged to obtain two data points, one describing heat and CO_2 rates before the maturation event and one after. A few days after flowering, in late May or early June, a decrease in metabolic rate occurs (fig. 1) and q/R_{CO2} increases (table 2). Not all populations flowered at the same time nor was the time-course of metabolism identical for the populations (table 2). The decrease in metabolic activity occurred during the week following May 27 for B51, B30, and B28, but not until the week following June 2 for B10 and B34, and the week following June 9 for U13. While a change from 15 to 25°C increased the respiration rate (R_{CO2}) by about a factor of two, efficiency decreased (see q/R_{CO2} values in table 2). That is, more of the available metabolic energy was lost as heat and was thus unavailable for growth at the higher temperature.

The temperature coefficient for heat rate (μ_q) was essentially the same for all populations, while the coefficient for respiration rate (μ_{CO2}) was much higher for B10 and B51 than for other populations (table 3).

In the laboratory drought experiment differences in metabolism were observed between the low, medium, and high watering treatments. As shown in table 4, heat rate, respiration rate, efficiency, and predicted growth at 15°C are all negatively correlated with increasing levels of water. Small burnet did better at 1/3 of field capacity than at higher levels of watering.

Alfalfa

All alfalfa cultivars had a Q_{10} for respiration (R_{CO2}) greater than 2 (table 5). Efficiency (q/R_{CO2}) was better at 15 than 25°C for four of the cultivars but showed little difference with temperature for Henry Mt. and Nomad. Predicted growth ($R_{SG}\Delta H_B$) was better at 15°C for all cultivars, except for Magnum.

The temperature coefficient for heat rate (μ_q), while more variable for alfalfa cultivars than for small burnet populations, was essentially the same for all cultivars (table 6). By contrast the temperature coefficient for respiration (μ_{CO2}) showed differences among the cultivars. Pooled data for all cultivars of alfalfa from the laboratory drought experiment (table 7) showed no trends with watering treatment.

Discussion

The spring and summer of 1997 were unusually wet and cool. It proved to be a poor year to try to assess the effects of drought in the field. This study should be repeated over several seasons to gain a true understanding of response in the field to temperature and soil moisture of populations of small burnet and cultivars of alfalfa. However, some conclusions can be drawn from this small beginning.

While both small burnet and alfalfa remain green and active all summer, they both grow best in the cool, moist spring months. The decrease in metabolism and growth a few days after flowering (fig. 1) may signal seed set and represent a shift from active growth to partial dormancy in order to survive the usual dry, hot summer months in the Great Basin. The strategy may be to conserve energy during the harsh summer months and grow more rapidly during better, even though cooler, conditions. This can be seen best with small burnet (table 2). The Q_{10} for respiration remains the same during the shift from early to late season, but the respiration rate decreases and q/R_{CO2} increases. These changes may indicate a shift in efficiency or in biochemical pathways, either in the respiratory substrate, or the composition of the biomass being produced. In growing tissues, rates of catabolism are known to depend on rates of anabolism. The story is similar for alfalfa (table 5).

At 15°C the populations of small burnet (table 2) ranked from highest predicted growth rate ($R_{SG}\Delta H_B$) to lowest were: B30>B51=B10>B28>B34>U13.
The alfalfa cultivars similarly ranked (table 5) by $R_{SG}\Delta H_B$ were:

Magnum>Spreader II>Ranger=Ladak 65>Henry Mt.>Nomad.

Conclusions

Small burnet and alfalfa have higher relative specific growth rates and higher efficiency (i.e. lower values of q/R_{CO2}) at 15° than at 25°C. Thus the rate of energy storage in structural biomass is faster at lower temperatures. Populations of small burnet and cultivars of alfalfa that show a decrease in metabolic rate later in the season will grow slowly but remain green longer. Small burnet seems to be more drought-resistant than alfalfa.

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Table 1--Field growth data on small burnet.

Population	Early Flower	Mature Flower	Growth
B51	May 19	May 19	Best growth early and late
B30	May 19	May 19	Good growth early slows down in June
B10	May 19	May 27	Poor growth early good late growth
B28	May 19	May 27	Poor growth early good late growth
B34	May 13	May 13	Poor growth early fair late growth
U13	May 13	May 13	Poorest growth early and late

*Early flower is when flowering stems first appear, mature flowers appear red. Flowering dates on Ephraim plants, growth descriptions based on Nephi plants.

Table 2--Values for q, R_{CO2}, q/R_{CO2}, and $R_{SG}\Delta H_B$ for each population of small burnet at 15 and 25°C early in the season (before late May or early June when a drop in metabolic rates occurred) and late in the season.

Pop.	q at 15°	R_{CO2} at 15°	q/R_{CO2} at 15°	$R_{SG}\Delta H_B$ at 15°	q at 25°	R_{CO2} at 25°	q/R_{CO2} at 25°	$R_{SG}\Delta H_B$ at 25°
Early in the Season								
B10	3.5	13.7	273	2.7	8.9	26.0	361	2.9
B28	3.9	14.3	292	2.6	9.8	27.1	365	2.6
B30	4.0	15.4	267	3.0	10.0	30.4	348	3.8
B34	3.7	13.3	298	2.4	9.7	26.7	377	2.4
B51	4.1	14.8	284	2.7	10.3	28.4	374	2.7
U13	3.8	12.6	313	2.0	9.4	25.6	380	2.2
Late in the Season								
B10	2.2	7.8	288	1.3	5.8	14.4	376	0.7
B28	2.6	7.7	381	0.9	6.8	14.7	506	-0.1
B30	2.6	6.5	412	0.4	6.2	12.4	525	-0.5
B34	2.6	6.7	401	0.4	6.2	14.0	467	0.1
B51	2.6	7.1	381	0.6	7.1	15.2	481	-0.2
U13	1.7	3.8	510	0.0	4.5	13.5	442	1.7

Table 3--Temperature coefficient of q and R_{CO2} for different populations of small burnet.

Population	μ_q	μ_{CO2}
B10	8.0	7.2
B51	8.1	6.2
U13	8.1	5.9
B30	8.0	5.6
B34	7.8	5.5
B28	7.9	5.4

Table 4. Laboratory drought experiment for small burnet. Data for all populations pooled. High water treatment is field capacity, medium water treatment is 2/3 field capacity, and low water treatment is 1/3 field capacity.

Water treatment	q at 15° (μW mg^{-1})	R_{CO2} at 15° (pmol mg^{-1}s^{-1})	q/R_{CO2} at 15° (kJ mol^{-1})	$R_{SG}\Delta H_B$ at 15° (μW mg^{-1})
Low	2.9	9.8	305	1.6
Med	2.4	7.0	373	0.8
High	1.9	4.9	443	0.4

Table 5--Average values for q, R_{CO2}, q/R_{CO2}, and $R_{SG}\Delta H_B$ for cultivars of alfalfa at 15 and 25°C.

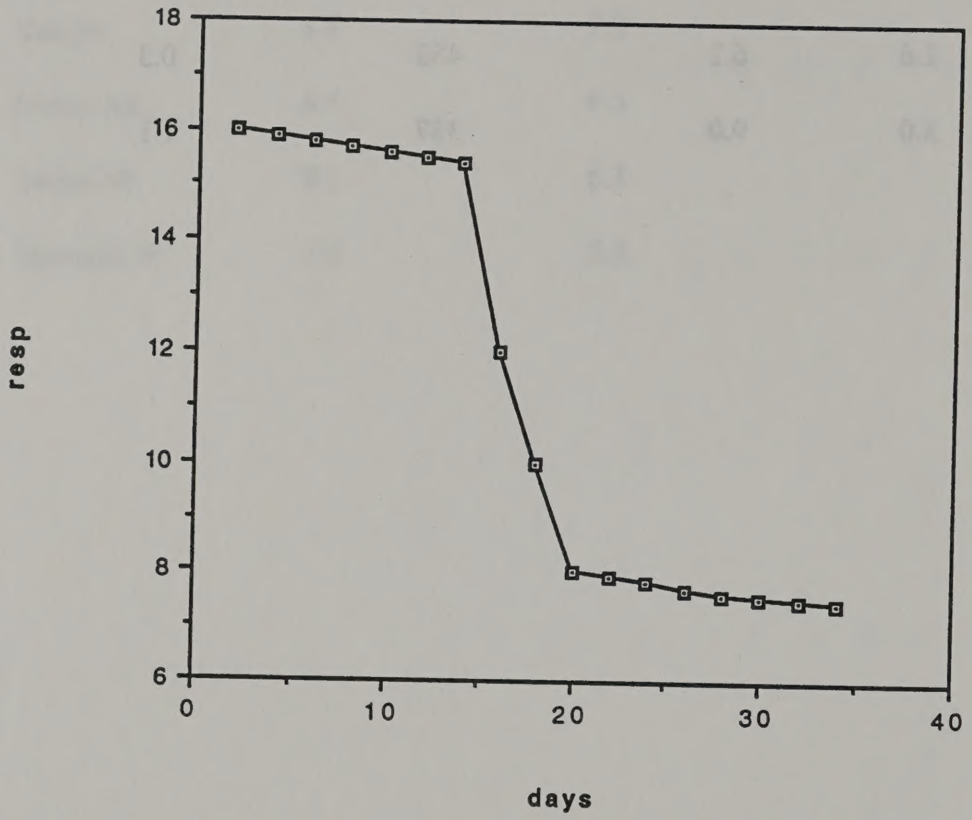
Cultivars	q at 15°	R_{CO2} at 15°	q/R_{CO2} at 15°	$R_{SG}\Delta H_B$ at 15°	q at 25°	R_{CO2} at 25°	q/R_{CO2} at 25°	$R_{SG}\Delta H_B$ at 25°
Henry Mt.	4.0	11.5	425	0.9	10.7	23.2	433	0.4
Nomad	4.4	12.0	411	0.6	11.4	26.5	435	0.7
Magnum	6.4	18.5	332	2.2	16.6	43.3	395	3.1
Ranger	4.6	12.7	363	1.2	11.5	25.5	470	0.1
Spreader II	4.8	14.9	333	2.0	12.1	29.5	395	1.5
Ladak 65	4.6	13.2	367	1.2	11.8	27.8	458	0.9

Table 6--Temperature coefficients of q and R_{CO_2} for cultivars of alfalfa.

Cultivar	μ_q	μ_{CO_2}
Nomad	8.1	8.1
Magnum	8.1	7.0
Ranger	8.7	7.0
Henry Mt.	8.5	6.5
Ladak 65	8.1	6.3
Spreader II	7.9	5.3

Table 7--Laboratory drought experiment for alfalfa. Data for all cultivars pooled. High water treatment is field capacity, medium water treatment is 2/3 field capacity, and low water treatment is 1/3 field capacity.

Water treatment	q at 15° (μW mg^{-1})	R_{CO2} at 15° (pmol mg^{-1}s^{-1})	q/R_{CO2} at 15° (kJ mol^{-1})	$R_{SG}\Delta H_B$ at 15° (μW mg^{-1})
Low	3.0	11.0	395	2.0
Med	2.6	6.2	453	0.3
High	3.0	9.0	357	1.1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Fourwing Saltbush Recovery after Burning and Clipping Treatments

Stephen B. Monsen, Darren G. Naillon

Problem

Fourwing saltbush (Atriplex canescens) is a valuable forage shrub adapted to a wide range of sites in the arid west. Fire tolerance has been observed for some populations but not others. Ecotypes of this species have demonstrated considerable variability in response to burning. The different response of fourwing saltbush sources to burning is in question. Most resprouting varieties occur in the Southwest and are not well adapted to the colder winters and drier summers of the Intermountain region thus making them poor germplasm to use in restoration or range improvement projects. These studies address the variability in response to burning of different sources of fourwing saltbush.

Methods

Nephi, Utah

Four sources of fourwing saltbush were planted at Nephi, Utah study site in 1989. Collections were obtained from the Uinta Basin, Utah; Winnemucca, Nevada; Elberta, Utah; and Rincon Blanco, New Mexico. Available plants were selected at random for treatment. Plants of each source were clipped and burned in 1993 and 1994. A burn barrel was used to regulate and control burning. The burn barrel equipped with propane jets was placed over each plant for the burning treatment. Plants were burned at two intensities. A short burn lasted 30 seconds and the long burn one minute. All leaves were removed by each burning treatment leaving only a skeleton of large branches intact. For the clipping treatment, all limbs were removed at the base of the plant leaving only the crown undamaged. Following the year of treatment each source was evaluated for survival and amount of regrowth. Survival data were analyzed using analysis of variance and mean separations. A general linear model of Student-Neuman-Keuls (SNK) test was performed at $p<.05$.

Myton, Utah

In August 1994, a trial was performed south of Myton, Utah to test recovery after burning of a fourwing saltbush population in its natural habitat. Three sites were used in the Five Mile Canyon area(UTM coordinates: Zone 12 561900 Easting 4419400 Northing) of the Diamond

Mountain Resource area, Vernal District, Bureau of Land Management. Sites was approximately one mile apart and separated by a small water drainage. At each location forty plants were selected and measurements of height, crown and vigor were taken. Plants were randomly selected for treatment. Twenty plants were clipped and twenty plants burned at each of the three sites. Treatments were applied in the same manner as the Nephi study site (see previous description).

Bell Rapids, Idaho

Approximately 40 different sources of fourwing saltbush were established in 1980 at Bell Rapids study site in southern Idaho. These study plots were evaluated to determine survival and performance at this location. All plants were burned by a wildfire in the summer of 1991. Subsequent ratings following burning were performed in 1992 and 1995. Data from the 1987, 1992, and 1995 ratings were analyzed. Twenty three sources of fourwing saltbush had sufficient plant survival from the original planting to include them in the analysis. Each plant was measured for overall height and crown. A vigor rating was assigned to help asses the condition of each plant. To compare the different sources an index of health was created from the information taken during each rating period. Height, crown and vigor ratings were given equal weight in contributing to the index value. Mean index values were applied in a statistical comparison using a general linear model of Student Newman Keuls test. P-values of less than 0.05 were considered significant.

Results and Discussion

Nephi, Utah

Treatments were harsh and represent the extreme of what the plant is capable of recovering from. Over both years and both treatments the source from the Uintah Basin, Utah had a significantly higher survival of 76 % compared to the other three sources. The Elberta, Utah source had 43 % survival and Rincon Blanco, New Mexico and Winnemucca, Nevada were 30 % and 27 % respectively (table 1). Survival was not significantly different among these three sources. Based on these findings the Uintah Basin fourwing saltbush germplasm material would be preferred in plantings where fire frequency is a concern. This material is adapted to cold winters and dry summers and would not likely die as a result of climatic conditions associated with the Intermountain Region.

Myton, Utah

This burning treatment was also extreme and recovery represents the plants ability to withstand severe conditions. Plants would not usually be subjected to herbivory grazing comparable to this clipping treatment under natural conditions. Low recovery following both treatments represent a worst case scenario for this fourwing saltbush source. Sites varied in survival despite being in close proximity to one another. Microsite conditions appear to effect survival of treated plants. One site had no plants recover from the burn treatment. Following the burn treatment 11.6 % of all the plants treated at three sites survived and resprouted. The clipping treatment had an 18.3 % survival following the treatment. The gender of the plant at the time of treatment had no bearing on survival. Male and female plants survived equally from both treatments. The first year following treatment, sprouting plants did not exhibit any reproductive traits. Comparing expected recovery of this source to others is somewhat limited as no other native sites of fourwing saltbush were tested to compare with these results. From this study one would expect at least limited recovery of fourwing saltbush following wildfire and extreme herbivory or plant damage.

Bell Rapids, Idaho

Using the index value previously described, plant materials at this site were evaluated for their ability to recover from burning. Only the Grand Junction, Colorado source had a statistically higher index value than all other sources. It's height, crown, and vigor combination was greater than all others. This source of fourwing saltbush is very large in stature compared to other sources.

There was no significant mortality directly related to the wildfire. The fire is thought to have burned through the planting relatively quick at a low temperature. The germplasm from Grand Junction is thought to be similar to the material from the Uintah Basin. Based on these studies consideration in using seed material from this region in restoration plantings could be advised.

Management Implications

When seeding fourwing saltbush is southern Idaho, or any other region, the source of the seed is relevant to meet management objectives. It is advisable to select a source with high expected survival following wildfires. This will maintain established stands even if wildfires frequently burn the area. Particular care should be taken to avoid planting material not adapted to the specific site or meeting management objectives.

From burning trials performed at Nephi, germplasm material from the Uintah Basin, Utah appears to recover well following burning. The Bell Rapids study shows germplasm material from Grand Junction, Colorado as being particularly large in stature. Considering the close proximity of the Uintah Basin and the Grand Junction collections to one another the material is thought to be similar. This material sprouts well following wildfires and produces good quantities of forage. Further testing of this material may be beneficial in further defining good attributes associated with it.

Table 1. Percent survival by treatment of fourwing saltbush at Nephi, Utah.

	Percent Survival			
Source	Uintah Basin	"Rincon"	Elberta, UT	Winnemucca, NV
Clipping Treatment 1993 and 1994	90	0	30	40
Burning Treatments 1993 and 1994	70	60	50	20
Total Survival of all Treatments	76[1]a[2]	30b	43b	27b

[1] Sample sizes of the burning treatment were twice as large as the clipping treatment thus giving them added weight in considering total survival percentages.

[2] Percent survival followed by the same lower case letter are similar ($P>0.05$).

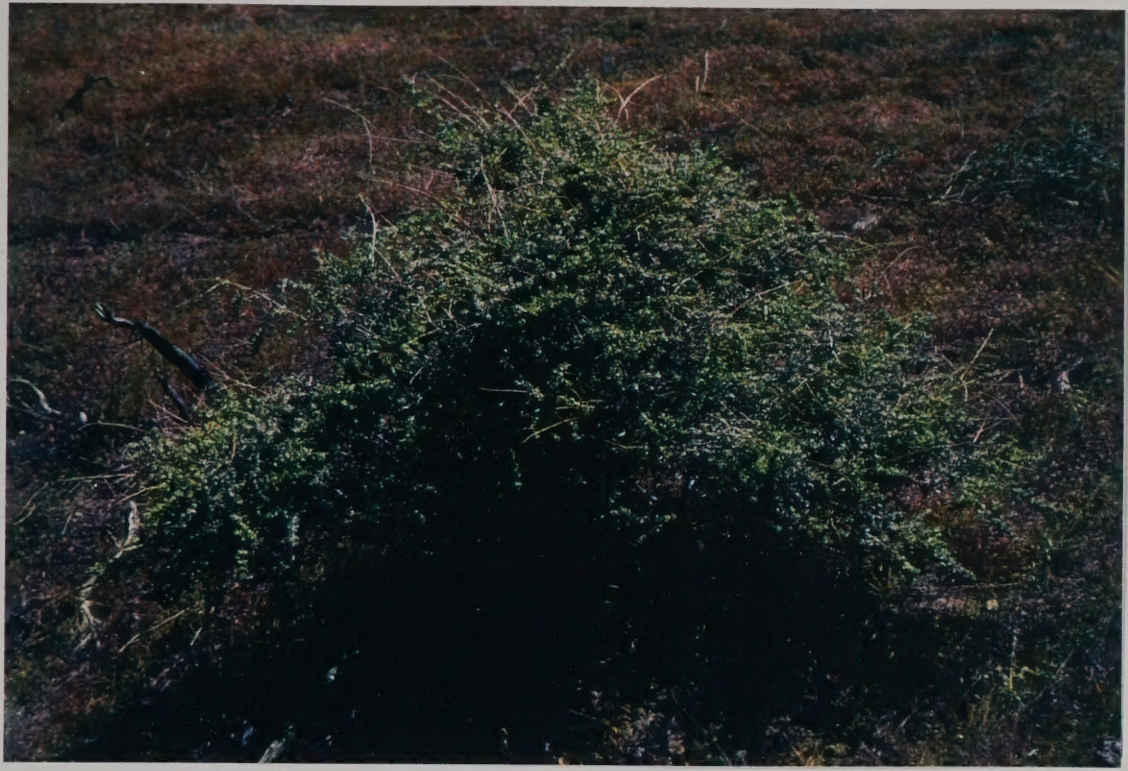

Figure 1. Fourwing saltbush south of Myton, Utah. This source sprouted well following burning in common garden trials at Nephi, Utah.

Figure 2. Burned fourwing saltbush plant south of Myton, Utah.

Variation in Burning Tolerance Among Forage Kochia Accessions

Stephen B. Monsen and Stanley G. Kitchen

Introduction

Shrub-dominated landscapes are characteristic of arid and semi-arid rangelands of the Intermountain West. Shrub dominance is favored by a combination of factors which may include low annual precipitation, low soil fertility, shallow soils, heavy grazing, and low fire frequency. Dominant shrub species of the West are generally not fire tolerant. In pre-settlement times, fire was either absent from these communities or it occurred infrequently on a relatively small scale (Whisenant 1990, West 1994). Where and when fire occurred, it acted as an agent of landscape-scale diversity.

Many shrublands are now threatened by the dramatic increase in fire frequency associated with the proliferation of exotic annuals, particularly cheatgrass (Bromus tectorum), into once stable shrub-dominated ecosystems (Whisenant 1990, Peters and Bunting 1994). These annuals produce large quantities of fine litter. This litter increases the quantity, flammability, and continuity of the fuel matrix of shrubland communities resulting in larger more frequent wildfires. After burning, the aggressive nature of these annuals inhibits reestablishment of perennials from seed, often altering the stable state from one that is shrub-dominated to one that is annuals-dominated. On some sites the change is associated with a single catastrophic event. As a result, vast acerages of big sagebrush (Artemisia tridentata), antelope bitterbrush (Purshia tridentata), salt-desert shrub and associated shrublands have been annualized while many surviving stands remain at risk. Responsible efforts to restore lost shrublands and to insulate surviving at-risk shrublands from the effects of the annuals/fire cycle must include consideration of adapted, fire-tolerant shrub species and ecotypes. Therefore, research efforts designed to evaluate the response of candidate species and ecotypes to burning are desirable and should be encouraged.

Forage kochia (Kochia prostata) is an introduced sub-shrub that has demonstrated drought and salt tolerance (Francois 1976), forage value for livestock and wildlife (Davis and Welch 1985), and seedling vigor in the face of competition from aggressive annuals (McArthur and others 1990). Growth begins in early spring and plants remain physiologically active until mid- to late-fall. A single cultivar, ‘Immigrant’, was released after evaluation of several germplasm introductions over a period of many years. ‘Immigrant’ has been successfully seeded on numerous severely degraded rangeland sites. Anecdotal observations of forage kochia post-burn recovery following wildfire have sparked renewed interest in examining variability within this genetically complex species.

Objectives

We evaluated the effects of season and duration of burn on post-burn recovery of 12 accessions of forage kochia. We also desired to distinguish between the effects on recovery of biomass removal and burn temperatures using severe clipping treatments for comparison. Finally, we examined differences in anatomical and physiological traits that might account for differences in post-burn recovery.

Methods

Preliminary burning trials were conducted on plants in existing adaptability trials in 1988 at Provo, Utah and in 1990 at Nephi, Utah and Orchard, Idaho. A 40-in diameter burn barrel with five adjustable propane-powered burners was used to apply burning treatments in a somewhat uniform manner. Burn intensity was adjusted by altering the period of time of burner operation for each plant. Short and long duration burns were arbitrarily set at 15 and 45 sec. of burner operation.

In 1990 approximately 80 greenhouse-grown transplants of 13 accessions of forage kochia were established in a spaced common garden at the Nephi study site. Initial establishment and growth was good for most plants of all but one accession. This accession was deleted from the study in 1991. Plant vigor and size were evaluated in the spring of 1991. Good to high vigor plants were selected for burning and clipping treatments. Six plants of each accession were used for each treatment. Burn treatments included; mid-season (July)/short (duration), mid-season/long, late-season (Sept.)/short, and late-season/long. A mid-season clip treatment (all branches removed at the crown) and control plants were used for comparison. In 1992, five plants per treatment were utilized for early- (June), mid- (July), and late-season (September) treatments of short burn duration. Companion clip treatments were also used for each season. Additional plants were sacrificed to determine total nonstructural carbohydrate (TNC) reserves in roots. Soil and vegetation water content was determined at the time of each burning treatment.

Survival was assessed during late summer, one year after treatment. Plant size and vigor of surviving plants was also determined in the field. All surviving plants were harvested following field evaluation. We determined stem number (by size class) for each of these plants. It was felt that this would be a conservative estimate of the number of latent buds to survive the burn treatment. Therefore, we expected that this number would be most relevant when compared to stem number for clipped plants.

In July 1994, a wildfire burned through forage kochia plots established as a common garden (1989) at the Whiterocks Road study site near Dugway, Utah. Fourteen accessions of forage kochia are growing on this site including the 12 studied at the Nephi site. The fire front moved quickly and the resulting burn appeared relatively uniform across all plots. Plant survival, size, and vigor was determined in the fall of 1995. Results were compared to those of the Nephi site burn studies.

Results and Discussion

Results of the 1988 and 1990 preliminary burn trials have been reported in corresponding IGRRP annual reports and will not be discussed in this work. Results of 1991 and 1992 controlled burn studies and recovery from the 1994 wildfire are partially analyzed and, although not the final word, major findings will be discussed here. A thorough analysis of data will be completed for journal publication.

Survival from 1991 and 1992 controlled burn and clip treatments are summarized in table 1. Survival across all burn treatments ranged from 38 to 85 percent among accessions with an overall mean of 67 percent. Survival across clip treatments ranged from 67 to 100 percent among accessions with an overall mean of 87 percent. Survival from 1991 short duration burn treatments was higher than that of long burns (table 2). Survival of 'Immigrant' plants was 95 percent from clipping treatments and 67 percent from burning treatments.

The effect of the season of treatment (burn or clip) on survival is summarized in table 2. Across all accessions, mean survival for 1991 mid-season burn treatments (63 percent) was lower than for late-season burn treatments (82 percent). This trend was reversed for 1992 burn treatments. Survival from 1991 mid-season clip treatments was lower than that of all 1992 clip treatments. Overall mean root-TNC percentage (1992 only) increased from 13.0 percent in June to 18.9 percent in September 1992.

Stem number of surviving plants varied among accessions and season of burn (table 3). As a general rule, number of stems and mean stem size were inversely related (data not shown). Many plants had numerous rudimentary stems and relatively few well developed stems, indicating an early determination of dominance. This pattern was not observed equally among all accessions, however. Of all accessions, 'Immigrant' produced the greatest number of post-burn and post-clip stems. More stems were produced following clip treatments than following burn treatments. There is a trend for more stems from 1991 burned plants (mean = 36) than from 1992 burned plants (mean = 26). A similar but weaker trend was observed for mean stem numbers between 1991 and 1992 clip treatments. Late-season burned and clipped plants tended to produce fewer stems than early-season treated plants. We observed no relationship between plant survival and mean stem number among accessions.

Compared to our controlled studies at the Nephi site, first-year survival following the 1994 Whiterocks wildfire was relatively high for all accessions (table 4). Mean survival for all accessions combined was 92 percent. There was no correlation between Nephi study and Whiterocks wildfire survival percentages. Mean vigor (scale of 1 to 5) of surviving plants ranged from 2.8 (including 'Immigrant') to 3.6. The vigor ratings appeared to be more a response to 1995 growing conditions at the site than a result of the wildfire.

The results of these studies present a complex picture for forage kochia recovery from fire. Clearly, plant vulnerability does not remain constant within a season or between seasons. We also conclude that fire-produced heat is not the only cause of mortality. We observed significant clipping-induced mortality suggesting that removal of above ground structures alone (without fire) can severely weaken forage kochia plants. Although an effect related to phenological stage of development is likely, it does not appear to be related to stored reserves. Our index of stored reserves, Root-TNC actually increased throughout the growing season while plant survivability following burn and clip treatments decreased. Lower stem counts for 1992 clipped and burned plants (compared to 1991 treated plants) suggest that plant age might effect latent bud behavior following fire.

Differences among accessions identified in the controlled experiment were not consistent between years and were not useful for predicting recovery at the Whiterocks site. We do not have an immediate explanation for this. Fortunately, all accessions of forage kochia we tested appear to be relatively well adapted to recover from the effects of fire, thus, future examinations of forage kochia germplasm might better focus on other desirable attributes.

Management Implications

These results confirm that 'Immigrant' and several other lines of forage kochia are well adapted for quick recovery from fire. This trait is probably coupled to the high level of grazing tolerance observed for the species. Managers who plan revegetation projects on semi-arid sites prone to invasion by weedy annuals such as cheatgrass and/or to high fire frequencies may consider seeding forage kochia as a means of establishing a fire-resilient shrubland ecosystem.

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Table 1. Survival of 14 accessions of forage kochia to burning and clipping treatments. Percentages are means of all 1991 and 1992 treatments combined.

Accession	P.I. Number	Burned	Clipped
		------------ survival percentage ------------	
U-1	330708	54	86
U-2*	314929	67	95
U-4	343101	85	90
U-5	356824	72	100
U-7	356822	47	81
U-8	356821	82	76
U-10	356826	85	95
U-11	356819	85	95
U-12	356820	38	67
U-13	356818	76	95
U-14	356817	49	88
U-20	358941	69	81
Mean		67	87

* 'Immigrant'

Table 2. Mean survival of burned and clipped forage kochia plants by year of burn and season of burn.

Treatment Year	Duration of Burn	Treatment[1]					
		EB	MB	LB	EC	MC	LC
		---------------- survival percentage ----------------					
1991	short	---	63	82	---	69	---
	long	---	50	75			
1992	short	75	78	52	97	95	70
	long	---	---	---			

[1] EB, MB, and LB are early- middle- and late-season burn treatments and EC, MC, and LC are early- middle-, and late-season clip treatments where June, July, and September correspond to early middle and late.

Table 3. Mean number of total stems for surviving burned and clipped forage kochia plants representing 12 accessions 1 year after treatment. Results are presented by accession and by year and season of treatment.

		Burn Treatment		Clip Treatment	
Accession	P.I. Number	1991	1992	1991	1992
		------------------- stem number -------------------			
U-1	330708	41	19	69	65
U-2*	314929	69	56	134	91
U-4	343101	38	28	103	58
U-5	356824	25	31	58	41
U-7	356822	38	21	102	65
U-8	356821	33	25	56	59
U-10	356826	42	21	70	50
U-11	356819	21	16	56	47
U-12	356820	49	20	28	90
U-13	356818	24	28	59	70
U-14	356817	20	24	62	74
U-20	358941	35	20	70	72
mean		36	26	72	65
Season of Burn					
Early (June)		---	35	----	78
Middle (July)		48	25	72	60
Late (September)		25	17	----	57

* 'Immigrant'

Table 4. Survival and vigor of forage kochia at the Whiterocks study site 14 months after being burned by wildfire (July 1994). Vigor is on a scale from 1 to 5 (high).

Accession	P.I. Number	Survival Percentage	Mean Vigor
U-1	330708	97	3.2
U-2*	314929	94	2.8
U-4	343101	95	3.3
U-5	356824	92	2.9
U-7	356822	98	2.8
U-8	356821	88	2.8
U-9	356825	95	3.0
U-10	356826	91	3.0
U-11	356819	87	3.5
U-12	356820	100	2.8
U-13	356818	82	3.6
U-14	356817	78	3.4
U-20	358941	96	3.1
	422519	94	3.0
Mean		92	3.1

* ‘Immigrant’

Forage Kochia Seed Germination Rate and Viability as Affected by Storage Conditions[1]

Stanley G. Kitchen and Stephen B. Monsen

Introduction

Forage kochia (Kochia prostrata) is a Eurasian low-shrub of broad geographic distribution introduced to the western United States for revegetation of severely disturbed arid and semi-arid sites (McArthur et al. 1974, Frischknecht and Ferguson 1984, Blauer et al. 1993). Numerous introductions have been evaluated for such traits as fire tolerance (Monsen and Kitchen 1998), livestock and wildlife preference (Davis and Welch 1985), establishment and competitive attributes (McArthur et al. 1990, Monsen and Turnipseed 1990), and salinity tolerance (Francois 1976, Romo and Haferkamp 1987). These studies demonstrate that forage kochia is well suited for rangelands receiving 15-30 cm. annual precipitation . A single cultivar, 'Immigrant', has been developed from this work. Several thousand kg of 'Immigrant' seed is planted most years.

Forage kochia fruits are commonly harvested from late October through January. Subsequently, current-year seed is sometimes not available in time for fall and early winter seeding projects. Forage kochia stand establishment from projects using seeds stored for one or more years in typical warehouse conditions is generally poor. This is due, at least in part, to the short shelf-life of the seeds of this species. Poor stand establishment success using high-viability, stored seeds is more difficult to explain.

To successfully emerge, forage kochia seeds must germinate at or near the soil surface. In the cold-desert environments to which this species is adapted, soil moisture conditions favorable for surface germination and seedling growth occur most dependably during brief periods in late winter and early spring. Seeds that germinate at other times (e.g. too late or too early) have a higher risk of mortality than seeds with the proper germination 'programming'. We suggest that poor establishment of forage kochia using high-viability, stored seeds can be due to changes in the germination programming associated with seed after-ripening.

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[1] A detailed report of this study has been prepared for publication in the Journal of Range Management. We anticipate publication sometime in the next 12 months.

Objectives

Our objectives were to examine in the laboratory among-accession differences in cold-temperature germination rate, or mean germination time (cold-MGT) expressed as days to 50% germination (based on total viable seeds), and determine the effects of different storage conditions on seed viability and cold-MGT for forage kochia. We also conducted field plantings of differently-stored seeds to test the conclusions drawn from laboratory experiments.

Methods

We conducted a preliminary experiment to determine among-accession differences in cold-MGT of forage kochia using three month-old seeds from 15 experimental lines collected from a common garden located near Boise, Idaho and one year-old 'Immigrant' seed. For each accession, four replications of 50 seeds each were placed in 15 x 100 mm plastic petri dishes on top of two germination blotters moistened to saturation with tap water. Petri dishes were arranged randomly in a cardboard box. The box was enclosed in a plastic bag to prevent desiccation, and placed in a walk-in cold room set at 2° C. Seeds were examined and germinants were counted and removed from the petri dishes on a weekly basis for 16 weeks. At the end of 16 weeks, the box was moved to a germination chamber set at 15/25° C (12 hr. alternating) for three days for final germination determination. Seed viability percentages and cold-MGT were then calculated for each replication.

In the Fall of 1992, seeds of four experimental lines were harvested from a nursery site in Spanish Fork, Utah for use in a storage effects experiment. Harvested seeds were dried, cleaned, and stored in cloth bags for approximately one month before further processing. 'Immigrant' seed was purchased for the same experiment from a commercial source. This seed had been collected in November 1992 from a 'wild' population located 15 km northeast of Milford, Utah.

In December, seeds of all five accessions were oven-dried (35° C) for 72 hrs. and subdivided into four equal sublots. One sublot for each accession was enclosed inside of each of four plastic bags. One of each of these bags was stored for 36 months in; 1) the laboratory (20° C), 2) the walk-in cold room (2° C), 3) a freezer (-15° C), and 4) a shed with no temperature control. Storage experiment germination procedures followed those used in the preliminary experiment. Each accession was tested fresh and each accession/storage combination was tested after 4, 8, 12, 24, and 36 months of storage.

We selected a fallowed agricultural field near American Fork, Utah as a site suitably uniform for field germination and seedling establishment experiments. Only 'Immigrant' seed was used for these field studies. Seeds had experienced approximately one and two years of storage prior to seeding. In preparation, each year 12, 0.2-g and 3, 2-g subsamples were weighed from each of the four 'Immigrant' sub-lots (storage treatments). We labeled and enclosed the 12, 0.2-g subsamples (approximately 150 viable seeds each prior to storage) in 10 x 10 cm square nylon-mesh bags. Bags were randomly sorted into 12 sets, each set including one bag from each storage treatment. Sets of bags were anchored in place with soil (1993) and straw mulch (1994).

In each year, three sets of bags were retrieved from the site one and two months following burial. Retrieved bags were packed in loose snow and taken directly to the laboratory for processing. Bags were then opened and the germination status was determined for each seed.

We seeded the 2.0-g samples on 12, 0.5 m^2 plots arranged in a randomized block design. Planting consisted of hand broadcasting seeds onto the appropriate plot and raking lightly over the entire plot to improve soil/seed surface contact and to anchor the seeds to the plots. The number of forage kochia seedlings per plot was determined in April in both years. At this time, the soil surface was dry and crusted and surviving seedlings had reached or passed the six-leaf stage.

The General Linear Model (GLM) was used to test for effects of storage treatment and time in storage on viability percentage and cold-MGT in laboratory experiments, and field germination and seedling survival in field experiments. Significant differences among accession and treatment means were determined using the Student-Neuman-Keul (SNK) method.

Results

For the preliminary experiment, cold-MGT ranged from 3 to 88 days, the shortest belonging to an accession collected from the Inner-Mongolia region of the People's Republic of China. Almost as short was the one year-old 'Immigrant' seed with a cold-MGT of 11 days. The mean value for the remaining accessions (all recently harvested seeds) was 54 days.

We observed significant differences in mean viability in response to storage treatments. Among accessions, viability percentages for fresh seed ranged from 66 to 93 percent (mean 77%). Mean viability for lab-stored seeds after 24 and 36 months was 49 and 24 percent. Mean viability for shed stored seeds after 24 and 36 months was 18 and 8 percent. Viability of cold room- and freezer-stored seeds did not differ significantly from recently-harvested seeds.

Cold-MGT for fresh seed-lots ranged from 51 to 108 days for the five accessions (mean of 71 days). However, we encountered germinated seeds as early as the second week for four of the five accessions, thus, within-accession synchronization of germination was low. After four months of storage, cold-MGT for lab- (50 days) and cold room-stored seeds (39 days) was significantly shorter than for shed- (64 days) and freezer-stored (68 days) or recently-harvested seeds. After eight months of storage, only freezer-stored seeds had cold-MGT values similar to those of fresh seeds. For 8 to 36 months of storage, cold-MGT for lab- and shed-stored seeds remained below 20 days while cold-MGT for freezer-stored seeds remained near 70 days. Cold-MGT for cold room-stored seeds was intermediate to these two extremes. 'Immigrant' seed responses were similar to those of other accessions.

Germination results from field retrieval experiments were similar to laboratory germination results. In both years of seeding, cold room- and freezer-stored seeds had significantly higher percentages of viable seeds ungerminated one month after planting than did lab- and shed-stored seeds. Nearly all viable seeds from all four storage treatments had germinated in the field two months after seeding.

Mean number of live seedlings counted on the emergence plots for cold room- and freezer-stored seeds was 224 (first year) and 288 (second year) compared to 26 (first year) and 6 (second year) for lab- and shed-stored seeds. Between-year differences were not significant.

Discussion

Forage kochia is well adapted to the sometimes severe and generally unpredictable conditions found in the cold-deserts of western North-America (McArthur et al 1974, Pendleton et al.1992). Although uniform seedling establishment may require disturbance, new seedlings are observed near established plants most years. Late-season seed maturation and a delayed/desynchronized germination pattern in cold temperatures produce a relatively high probability that some fraction of seeds will germinate at a time of winter or spring with a high probability for establishment success. The annual variability of that window of opportunity favors the selection of a bet-hedging germination pattern. Desynchronization of forage kochia germination accomplishes that need. Too early or too uniform germination may place a large percentage of seedlings at risk to conditions unfavorable for survival.

We believe that among accession differences in MGT for freshly collected seeds are adaptive, probably reflecting climatic differences in the Eurasian origins of the respective accessions. However, we have insufficient knowledge concerning those origins to speculate on their meaning. Germination patterns for freshly collected seeds of all accessions that we have tested (with the exception of the Chinese source) appear to be well enough adapted for establishment in the cold-deserts of western North America.

Although cold-MGT varied among accessions from 51 to 108 days initially, cold-MGT for all accessions fell to between 21 and 12 days after just eight months of lab storage. This clearly indicates that cold storage practices will be required for any and all accessions to preserve a prefered germination profile.

Management Implications

This study has provided strong support for the little understood explanation for forage kochia seeding failure when using after-ripened seeds of known high viability. It indicates that low temperature germination for fall- and winter-seeded forage kochia seeds should be delayed and desynchronized for best probability of success. When seeds are not planted soon after harvest, we recommend that seeds be dried to less than 7% moisture, sealed in water tight containers, and stored at temperatures below 5° C. We believe that there may be an additional advantage to storing seeds at temperatures below freezing. Finally, after-ripened seeds may be suitable for spring or summer plantings where supplemental irrigation is available.

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A 52-Year Ecological History of Selected Introduced and Native Grasses Planted in Central Idaho

Stephen B. Monsen and Val Jo Anderson

Introduction

Thousands of hectares of shrublands in the Western USA have been seeded with introduced grasses as a substitute for understory native herbs. Many introduced graminoids demonstrate excellent establishment attributes and perform well under intensive grazing (Hafenrichter et al. 1968). Many successful introductions exist in edaphic and climatic areas similar to western rangelands. Some are genetically similar to certain native species (Dewey 1984), and many taxa are circumboreal but exhibit considerable variability in morphology (Welsh et al. 1987).

The influence of introductions upon species composition and successional development of native plant communities is a vital consideration. While introductions are widely successful, perpetuation of the native shrub-forb association is also essential. The longevity and perpetuation of selected introductions and native species has not been determined. Studies are required to determine the ecological relationship between principal introduced grasses and native communities in which they are planted. This study was designed to investigate the longevity of a number of introduced and native grasses and to evaluate variability in plant longevity among ecotypes.

Methods

In 1939, researchers fall planted 97 species on a mountain big sagebrush-bluebunch wheatgrass (Artemisia tridentata ssp. vaseyana-Agropyron spicatum) site in south-central Idaho, Boise National Forest. More than one accession was planted for several species resulting in 132 entries being tested. Of the species, 53 were introductions, 10 were indigenous, and 34 were native to the general area but not to the sagebrush-bluebunch wheatgrass community. Soils at the study site are Typic Argixerolls with a fine loam texture and a depth of 76 cm. Average annual precipitation is 40 cm. The site was protected from livestock grazing throughout the study.

The experimental design was a completely randomized block with two replications. Each accession was planted in three rows spaced 40 cm apart in 3 x 3 m plots. On each evaluation date each plot was ranked 0-5 for the number of plants remaining (plot ranking). A second 0-5 ranking second 0-5 ranking evaluated the percentage of the three rows occupied by seeded plants (distribution ranking). Both rankings were summed to provide a relative rating. Plantings were reevaluated annually for 10 years following seeding; thereafter evaluations were conducted in 1972, 1980 and 1991. Yearly relative ratings were evaluated using analysis of variance and Duncan's Multiple Range Test for mean separation ($\alpha=0.05$).

Results

Of the 132 accessions planted in 1939, 40 survived 10 years. The 40 accessions included 34% of the introductions, 38% of the indigenous species, and 18% of species native to the general area. By 1972, or 32 years after seeding, 21 accessions survived, which included 19% of the introductions, 27% of the indigenous species, and 3% of the general native species. By 1980, only 17 accessions remained and included 16% of the planted introductions, 19% of the indigenous species, and 3% of the native species. In 1991, 52 years after planting, 14 accessions persisted. Only 15% of the introductions and 15% of indigenous remained.

After 52 years, intermediate wheatgrass (Agropyron intermedium), sulcata sheep fescue (Festuca ovina ssp. sulcata), Fairway crested 0 wheatgrass (Agropyron cristatum), bluebunch wheatgrass (Agropyron spicatum), and western wheatgrass (Agropyron smithii) were rated the most successful species (Table 1).

Nearly all species that survived for 32 to 52 years were represented in the planting by more than one ecotype. Differences in longevity were recorded among accessions indicating ecotypic variation. Most ecotypes of intermediate wheatgrass, including pubescent wheatgrass (Agropyron trichophorum), survived for 52 years, but some were less abundant than others. Three ecotypes of sheep fescue failed to survive for 10 years, but one was ranked highly successful. Fairway crested wheatgrass was much more abundant and persistent than standard crested wheatgrass (Agropyron desertorum). Differences in ecotypic performance were also recorded among accessions of bluebunch wheatgrass. One ecotype persisted extremely well, whereas two ecotypes provided only weak stands after 32 years.

A number of indigenous species failed to persist for over 32 years. Some quite common species in this category include Idaho fescue (Festuca idahoensis), prairie junegrass (Koeleria cristata), mutton bluegrass (Poa fendleriana), Sandberg bluegrass (Poa secunda), bottlebrush squirreltail (Sitanion hystrix), needle-and-thread grass (Stipa comata), and Thurber needlegrass (Stipa thurberiana) Species longevity was more closely related to individual ecotypes than between exotic or endemic collections.

Discussion and Conclusion

Only a small percentage of species persisted for 32 or 52 years while many initially established, only 30% survived for the first 10 years. By 1972, this number declined to 16%; by 1980 and 1991 the numbers were 13% and 10%, respectively. Apparently some introductions are as equally adapted to the study site as indigenous species that evolved with the native community. When seeded with native species, some introductions can be expected to persist and remain a dominant component of the community.

Species persistence and longevity varied among ecotypic collections. Most species that persisted for 32 or 52 years generally were represented with ecotypes that survived for shorter periods. Most ecotypes of intermediate wheatgrass were aggressive, long-lived and extremely persistent perennials. In contrast, ecotypes of crested wheatgrass, sheep fescue and bluebunch wheatgrass varied in longevity. Fairway crested wheatgrass is much better adapted to more mesic big sagebrush communities than is standard crested wheatgrass. Selections of sulcata sheep fescue are also better adapted to this sagebrush site than are other accessions of sheep fescue and hard fescue (Festuca ovina ssp. duriuscula).

Ecotypic variability of bluebunch wheatgrass is an important feature of this species. Numerous sites that once supported this bunchgrass have been seeded to introduced species or have been invaded by introduced annuals. Land managers need to be able to identify ecotypes that can persist for extended periods amid competition. One ecotype persisted well with other species and was capable of surviving with intense competition. Plantings of western wheatgrass survived equally well and demonstrated capability to persist for long periods.

An important number of native bunchgrasses included in this study are not typically long-lived. Plantings of Idaho fescue, prairie junegrass, bottlebrush squirreltail, Sandberg bluegrass, and needle-and-thread grass survived approximately 30 years. Natural recruitment would be required to perpetuate these species. If seeded with more persistent grasses, it is unlikely the native grasses would persist for long periods. While this study reports longevity in a protected environment, grazing would affect plant survival.

Management Implications

This study confirms that site adaptation and longevity are genetically regulated traits of perennial grasses. Ecotypes or cultivars of all perennial grasses seeded in range and wildlife restoration projects differ in site adaptability. In addition, longevity and natural recruitment are directly related to site adaptive features. Individual ecotypes may not be adapted to particular sites, yet may persist for 30-40 years before they succumb. Seeding persistent introduced species including crested wheatgrass can prevent natural recruitment and displace various native species such as Sandberg bluegrass, Thurbers needlegrass, bottlebrush squirreltail, and needle-and-thread grass.

These native perennials persist for approximately 30 years, and require natural recruitment to persist. More aggressive and persistent individual plants of crested wheatgrass and hard fescue can gain dominance by restricting seedling development of these species.

Differences in site adaptability and longevity were recorded among ecotypes of bluebunch wheatgrass, which confirms that locally adapted ecotypes are planted.

Technology Transfer Products

Publications

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Table 1 Relative ratings, an index of plant density and distribution of 14 species and ecotypes that persisted for 52 years

Species	1949	1972	1980	1991
	Relative ratings			
Agropyron trichophorum	10.0 A[a]	9.5 AB	5.0 ABC	5.0 CDE
Agropyron intermedium	9.5 A	10.0 A	9.0 AB	10.0 A
Agropyron spicatum	9.0 A	7.0 BC	7.0 ABC	7.5 ABC
Agropyron smithii	9.0 A	8.0 AB	6.5 ABC	6.0 ABCD
Agropyron sibiricum	8.5 AB	7.5 AB	5.0 ABC	3.0 DE
Agropyron desertorum	8.5 AB	2.0 DE	2.0 C	3.0 DE
Agropyron cristatum	8.5 AB	9.5 AB	10.0 A	9.0 ABC
Elymus cinereus	8.0 AB	9.0 AB	9.5 A	5.5 BCD
Agropyron elongatum	8.0 AB	8.0 AB	5.0 ABC	5.0 CDE
Festuca ovina spp. sulcata	7.5 AB	9.0 AB	10.0 A	9.5 AB
Stipa viridula	5.0 BC	2.0 DE	2.0 C	2.0 DE
Agropyron spicatum inerme	4.0 C	1.0 E	2.5 C	2.0 DE
Elymus junceus	2.5 C	4.5 CD	5.5 ABC	1.0 E
Bromus inemis	2.0 C	4.0 D	4.0 BC	3.0 DE

Years (spanning 1949–1991)

[a] Numbers within years with similar letters do not differ significantly at $\alpha = 0.05$

Comparison of Burning Reliance of forage kochia, crested wheatgrass, bluebunch wheatgrass, small burnet, and western yarrow in Simulated Burned Greenstrips

Stephen B. Monsen and Kelly L. Memmott

Introduction

Vegetative composition of the semiarid shrubland within the Intermountain region has changed significantly in past century. Various perennial grass/shrub communities are now occupied by an annual grasses of primarily Cheatgrass (*Bromus tectorum*). The transition has resulted from grazing and an increase in fire frequency. Fire intervals within the annual cheatgrass sites has increased to periods as frequent as every 3 to 7 years. Extensive burns now regularly occur within the Intermountain region. As the fires advance each year the expenses to contain them and to restore the rangelands increases. Planting greenstrips in strategic locations has proven to be successful to contain and prevent fires spread.

Recent studies have shown that certain plants can be spaced at optimum distances to control understory weeds and create a fire break at the same time. The Idaho BLM has had success with forage kochia and crested wheatgrass as greenstrips as the primary species. This study will use different strains of forage kochia, western yarrow, crested wheatgrass, small burnet, and bluebunch wheatgrass to investigate the positive traits of these plants in a greenstrips situation.

Study Objectives

The principle objective of this study was to determine and select species that would deter fire in a wildfire situation and serve as greenstrips. Plant growth and vegetative characteristics that were important in controlling fire spread was also evaluated. Studies were designed to simulate a wildfire and record the characteristics of the fire as it confronts the different species.

Methods

In the spring of 1993 a 225 x 600 ft section of land was divided into sections 30 ft x 60 ft with a 20 foot innerspace to serve as a barrier. A grid of five plots wide by eight plots long was established. Ten different species or accessions were randomly planted in each of three plots. The plant species were: forage kochia (Kopr B2-88, B13-88, B17-88, B10-89), bluebunch wheatgrass (Agsp B53-88), siberian wheatgrass (Agcr) small burnet (Sami- delar), western yarrow (Acmi B35-87, B35-88, Acmic B5-87), and a control. Kochia and yarrow accessions were planted at 36 inch spacings, grasses and small burnet were planted at 24 inches.

Plantings were allowed to establish for a period of five years. During this time no attempt was made to control weeds. In the fall of 1996 annual wheat was drill seeded into all innerspaces around each plot as well as the other half of the 30x60 plot. The wheat provided a uniform and dense stand of dry litter that simulated the effect of a heavy stand of cheatgrass in a fire situation.

In late summer of 1997, sample plants, of each species were cut and weighed in each plot. Green weight, as well as dead standing weight were recorded. Percent litter was also determined. Plant tissue were then dried and later weighed to gather percent moisture of the live and dead materials (see table 2). This was also done for the annual wheat (see table 3.). Biomass was determined for each plot. Soil samples were collected at two depths; 0-6" and 6-12". Percent moisture was determined and recorded (see table 4).

At the time of the burning a small portable weather station was used to record climatic conditions. This included wind speed and direction, humidity and temperature. An 8mm video camera was used to record the fire as it burned into the plots to aid in determining flame length, speed of fire, and duration of fire in the plot. A SRL 35mm camera was also used to produce slides for presentation use and general information.

Burning was conducted during a 2-day period in early October, 1997. Practice plots were burned first to achieve synchronicity. Within each plot, fire was started with the use of two propane burners by igniting the southern portion of the plot and letting the wind carry the fire into the greenstrips plants. It was found that the annual wheat did not provide enough fuel to carry a fire so two bales of dried straw were spread across each plot to facilitate the fire. The straw was only applied to the wheat not the greenstrip plant. This addition proved to be successful.

Results and Discussion

The temperature at the time of the burning of all plots ranged between 73 to 85 degrees Farenheit. Wind speeds ranged from 10 to 15 mph with gusts recorded up to 27 mph. The three accessions of kochia differed in the ability to restrict and control movement of a fire. Kopr B2-88 (Immigrant kochia) performed well in the three plots of allowing the fire to burn into the plot an average of two feet before the fire diminished. This was due to the greenness of this variety and the amount of young recruitment of plants in the understory. Wind speed at the time of burning averaged 16.3 mph. Kopr B10-89 a source which produced a substantial amount of litter during the previous 5 years growth, burned more easily, but only if winds were above 20 mph.High wind would cause the fire to pre-heat and dry out the plants causing them to ignite and burn. However, the flame length was greatly reduced when the fire met the kochia (see table 1). The duration of the fire was much longer in the kochia (5 minutes) than in the grass (30 seconds). Kopr B13-89 burned differently depending on the wind speed. When the wind was below 20 mph this source contained the fire, but when wind speed exceeded 20 mph the fire would eventually but slowly burn through the plot. Kopr B17-89 was severely damaged by rodents the previous winter by girdling the trunks and killing the plants. This had an affect on the burn as the fire advanced much further among the dead plants. Wind speeds of 27 mph was able to burn a mosaic pattern within the dead shrubs.

Accesssions of yarrow differed in their ability to control movement of fire. All accessions tested caused a reduction in flame lenght as fire moved from the dry grass to the planted plots. Flame lenght decreased from 10-15 feet to 1-4 feet. Wind speeds below 20 mph did not carry fire into the yarrow plots. Winds above 20-27 mph were able to carry a slow erratic fire through dry litter. Fires did not burn a uniform front through the plots, but burned a mosaic of 15 -20 feet into a plot if winds remained high. Accession Acmi B38-88 produced more upright growth, but litter content was not much greater than other selections. Yarrow accessions were able to contain fires and reduce flame length and burniong intensity.

Bluebunch wheatgrass (Agsp B53-88) plants produced fine green stems causing fire to decline as the flame spread from the dry wheat into the plantes perrenial grass. Flame length decreased from 10-15 feet in the annual wheat to 2-3 feet in the bluebunch wheatgrass. Wind speeeds of14-16 mph did not carry fire into the perrenial grass plot.

Crested wheatgrass plots burned more freely than did bluebunch wheatgrass. Flame length in the crested wheatgrass varied between 3-4 feet, compared to 10-15 feet in the annual wheat. Winds exceeding 20 mph were able to carry a fire in the created wheatgrass, if winds decreased below 16 mph, the fuel would carry the fire.

Plantings of small burnet were extremely effective in containing a fire. Wind speeds exceeding 20 mph were not able to advance fire into the planted burnet. Fires completely stopped when burned into this broadleaf herb.

Management Implication:

Plants selected for this study demonstrate the usefulness to serve as grenstrips of fuel barriers to control wildfires. All species that were evaluated provide a competative stand that is capable od eliminating understory annual weeds that carry a fire. Species of forage kochia, western yarrow, small burnet can be used as greenstrip planting within areas they are adapted. Plants established at intervals of 30 inches appear best suited to control annual weeds, yet reduce creation of a continuous fuel supply to carry a fire. Wind speeds exceeding 20-25 mph are required to move a fire into plots of forage kochia and western yarrow. All species cause a rapid decline in flame length aand burning intensity. Flame lengths decrease from 10-15 to less than 3-4 feet with all species. Fires did burn into plots od forage kochia and yarrow if dead, dry matter occured. However, fires burned slow and erratic.

Individual accessions of forage kochia and western yarrow burned somewhat differently, indicating selection for fire resiliance is practical. However, selection aaand use of adpated ecotypes in arid situations is advised. Management of stands by periodic grazing, mowing, or controlled burning is advisable to reduce litter and maintain healthy stands.

Fire barriers or greenstrips using a combination of species is practical and advsisable.

Relevant Publications

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Table 1.--Climatic conditions, flame length and duration of fire of annual wheat and planted species plots

Plant Species	Temp (F)	wind mph	time in grass (sec)	Flame length in grass (ft)	Flame length in plot (ft)	Distance of burn into planted species plot (ft)
Agsp B53	80	16	21	10-15	2-3	30
Agfr	84	23	19	10-15	2-4	23
Kopr B2	82	16	25	10-15	1	2
Kopr B10	80	20	27	10-15	5	25
Kopr B13	84	19	21	10-15	3	21
Kopr B17	77	18	29	10-15	6-7	28
Acmic B5	85	17	25	10-15	1-2	20
Acmi B35	84	12	30	10-15	2-3	12
Acmi B38	85	16	22	10-15	3-4	30
Sami delar	79	17	25	10-15	0	.5

Table 2. Weight of plant samples, % litter, and % moisture

Plant Species	Weight of Plant	Weight of Plant		%water	%water
	live	standing litter	%litter	live	litter
Agsp B53-88	110	53	33	30	2
Agfr	233	96	29	29	0
Sami (delar)	198	0	0	43	0
Acmic B5-87	116	76	40	35	0
Acmi B35-87	436	70	14	48	2
Acmi B38-88	345	139	29	28	1
Kopr B2-88	429	361	46	33	9
Kopr B10-89	658	341	34	33	14
Kopr B13-89	514	185	26	37	12
Kopr B17-89	1399	518	27	37	6

Table 3. Dry weight of annual wheat in selected burn plots

Plot #	1/4m square grams	83.7m plot kilos
504	132.1	44.2
701	133.5	44.7
705	147.8	49.5
205	111.5	37.3
201	167.7	56.1
102	131	43.9
Average	**137.3**	**46.4**

Table 4. Soil Moisture from Nephi samples

Plant Species	0-6" % Moisture	6-12"% Moisture
Sami (delar)	9.92	7.54
Agfr	9.66	10.77
Agsp B53-88	9.08	9.82
Kopr	12.92	10.01
Acmi	10.19	9.92
Control	14.99	12.69

Photo 1. As fire burned the annual grass flames reached 10-15 feet and averaged a speed of one foot per second.

Photo 2. When fire reached the kochia and other plants the flames and speed of the fire were significantly reduced.

Breeding Fire Tolerance into Antelope Bitterbrush

Stephen B. Monsen, Darren G. Naillon

Introduction

Ecotypic variability in burning resilience is common for some shrubs native to the Intermountain region. Some ecotypes of antelope bitterbrush (Purshia tridentata) recover from burning by crown sprouting. Erect growth forms are common throughout most lower elevations in southern Idaho and do not recover from even moderate burning. It has been observed that prostrate or low growing varieties of antelope bitterbrush sprout and are capable of recovery following fires. As fire frequency has increased within the past 25 years many stands of antelope bitterbrush that once existed in southern Idaho have been eliminated. The upright forms of this species provide good winter forage for wildlife and are an important element of the mixed shrub/grass communities.

Objective

The objective of this study is to investigate if fire tolerance traits can be incorporated into upright forms of antelope bitterbrush by breeding with fire tolerant ecotypes. If possible, reestablishment of former populations of antelope bitterbrush could be achieved through interstrain breeding.

Methods

Seed from three collections or ecotypes of antelope bitterbrush were obtained from native stands near Shoshone, Idaho. In 1990 each source was planted in a one acre field at the Jerome, Idaho study site. These fields provided the maternal stock for interstrain breeding. In 1994, pollen from four known sprouting populations of antelope bitterbrush were artificially hybridized with plants of the three southern Idaho ecotypes growing at Jerome. The paternal pollen sources were: 1)Reynolds Creek, Idaho; 2)Craters of the Moon, Idaho; 3)Bryce Canyon, Utah; and 4)Oaks, Ephraim Canyon, Utah. Ten shrubs from each of the three maternal sources were selected for crossing with the four pollen sources. Flowering branches were bagged shortly after buds had formed but before the flowers opened. Four white paper sacks were placed on branches of each individual plant. Pollen collected from the four paternal crossing sources was individually placed inside a separate paper sack. Pollen was stored in coolers to synchronize pollination. After pollination had occurred the paper sacks were removed and mesh sacks were placed over each branch to allow complete seed development. Confidence of obtaining hybrid crosses is greater than 95% as bitterbrush is an obligate out crosser(Pendleton 1994). Seeds were harvested and cleaned. Amount of seed produced by each interstrain cross was recorded (Table 1). The F1 progeny was reared in a greenhouse and transplanted to Jerome in spring of 1995. Interstrain crosses and available paternal and maternal transplants were planted in a random block design. Figure 1 provides the planting map of interstrain crosses and parent materials. Sixty-four plants of each interstrain cross were planted in each block. Plantings established and grew well during the summer of 1995 through 1997. In late summer of 1997 ten plants from each block were burned with a propane torch. Plants were evaluated in late fall to determine sprouting (Table 2).

Results and Discussion

This study as it is still in the preliminary stage and few conclusions can be drawn at this date. The interstrain crosses have been burned once in late summer of 1997 and sprouting was recorded in early winter of 1997. Preliminary sprouting results are reported in tables 2 and 3. No statistical tests have been performed due to insufficient data. It appears that all interstrain crosses with the paternal source Reynolds Creek have sprouted less than other interstrain crosses. Only three individual plants from Reynolds Creek crosses sprouted three months after burning. Eighteen sprouting plants were recorded from crosses with Ephraim Canyon paternal source, 15 from Craters of the Moon, and 11 from Bryce Canyon. The maternal source B201 had the highest number of sprouting individuals compared to B210 and B211. These differences may not be significant. Further testing will help confirm these conclusions. Antelope bitterbrush often sprouts and then completely dies. The plants will be evaluated again in spring and fall 1998 and 1999 to evaluate long term recovery from burning by each interstrain cross. Spring and fall evaluations will be conducted to determine if dieing off occurs after sprouting. Additional burning will be conducted in 1998 to replicate treatments across multiple years. Stem and root segments will be examined to determine if differences in meristematic tissue characteristics leads to sprouting .

Management Implications

If an interstrain cross can be created which will sprout following wildfires then managers may have an additional resource to restore antelope bitterbrush to sites subjected to frequent burning. To be functional seed would have to be initially developed through artificial or controlled breeding programs. The ecological implications of sustaining a population derived from interstrain crossing is not known. However, it is apparent that frequency of fires has nearly eliminated native sources of antelope bitterbrush throughout southern Idaho. Attempts to retain this shrub deserves some consideration. The restoration of antelope bitterbrush areas would provide much needed wildlife habitat and be a step to improve a dwindling ecosystem. Fire tolerant antelope bitterbrush would allow for less maintenance in the long term of some of our arid regions.

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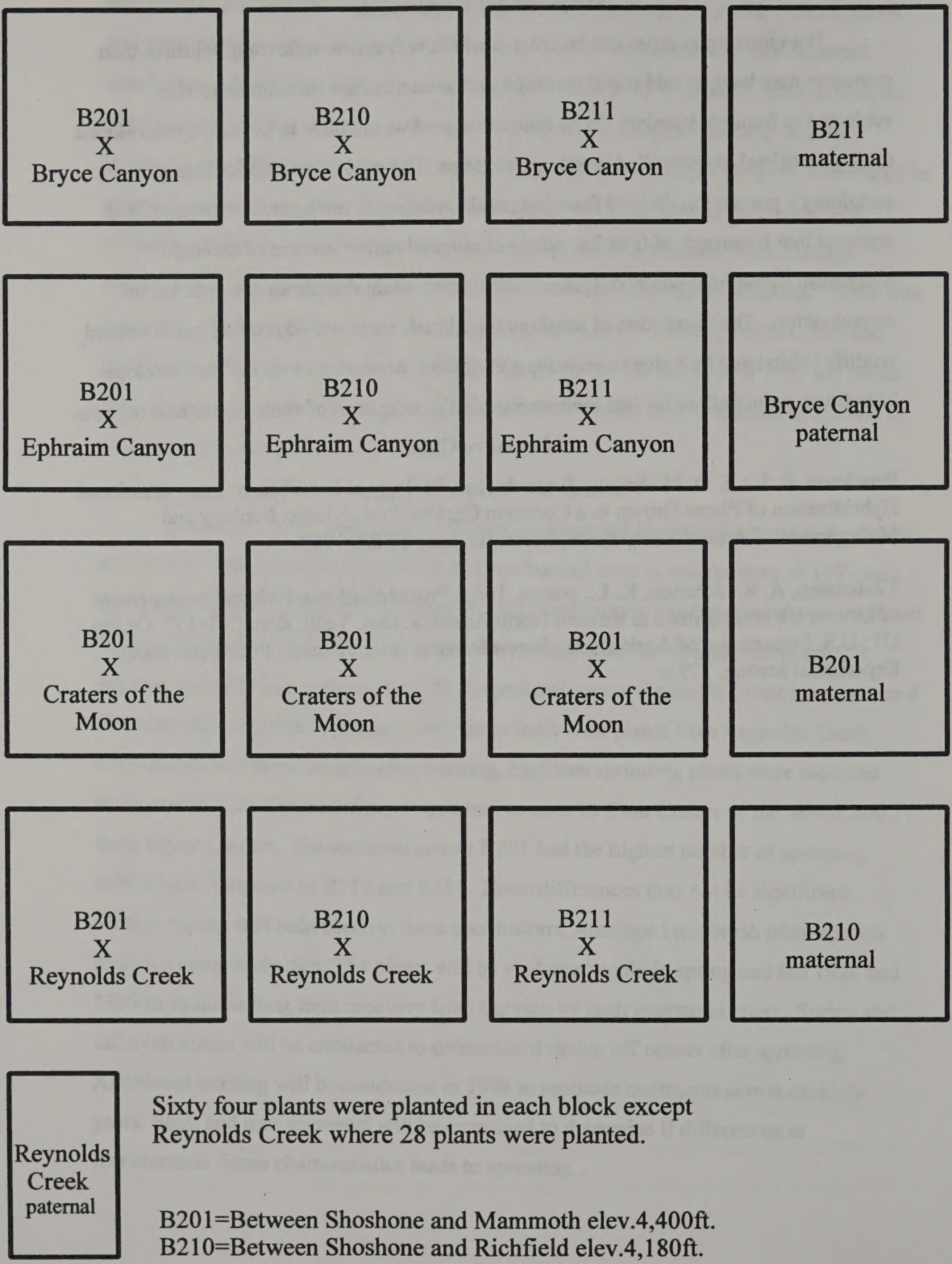
Figure 1. Antelope Bitterbrush interstrain cross planting map for Jerome, Idaho.



B201 X Bryce Canyon	B210 X Bryce Canyon	B211 X Bryce Canyon	B211 maternal
B201 X Ephraim Canyon	B210 X Ephraim Canyon	B211 X Ephraim Canyon	Bryce Canyon paternal
B201 X Craters of the Moon	B201 X Craters of the Moon	B201 X Craters of the Moon	B201 maternal
B201 X Reynolds Creek	B210 X Reynolds Creek	B211 X Reynolds Creek	B210 maternal
Reynolds Creek paternal			

Sixty four plants were planted in each block except Reynolds Creek where 28 plants were planted.

B201=Between Shoshone and Mammoth elev.4,400ft.
B210=Between Shoshone and Richfield elev.4,180ft.
B211=Near Shoshone elev. 3,755ft.

Table 1. Number of seeds produced from ten plants of each interstrain cross.

	PATERNAL SOURCES			
MATERNAL SOURCES	Bryce Canyon	Ephraim Canyon	Craters of the Moon	Reynolds Creek
B201	135	185	125	140
B210	390	290	140	185
B211	180	165	200	140

Table 2. Number of antelope bitterbrush interstrain cross plants that sprouted following burning. Ten plants were burned of each interstrain cross.

	PATERNAL SOURCES				
MATERNAL SOURCES	Bryce Canyon	Ephraim Canyon	Craters of the Moon	Reynolds Creek	Total maternal plants sprouting
B201	5	9	4	2	20
B210	3	4	5	0	1 (40 possible)
B211	3	5	6	1	15
Total paternal plants sprouting	11	18 (30 possible)	15	3	

Table 3. Number of plants by parental sources that sprouted following burning of 10 plants.

Parent Source	Number of plants sprouting	Percent of plants sprouting
B201	3	30%
B210	3	30%
B211	1	10%
Bryce Canyon	4	40%
Reynolds Creek	1 of 6[1]	16%

Seed of Ephraim Canyon and Craters of the Moon were unavailable at the time of seedling rearing.

[1] Only six plants were available for burning from Reynolds Creek.

Note: B201, B210, B211 are index numbers specifically assigned to sources of seed from different collection sites. All these collections originate near Shoshone, Idaho.

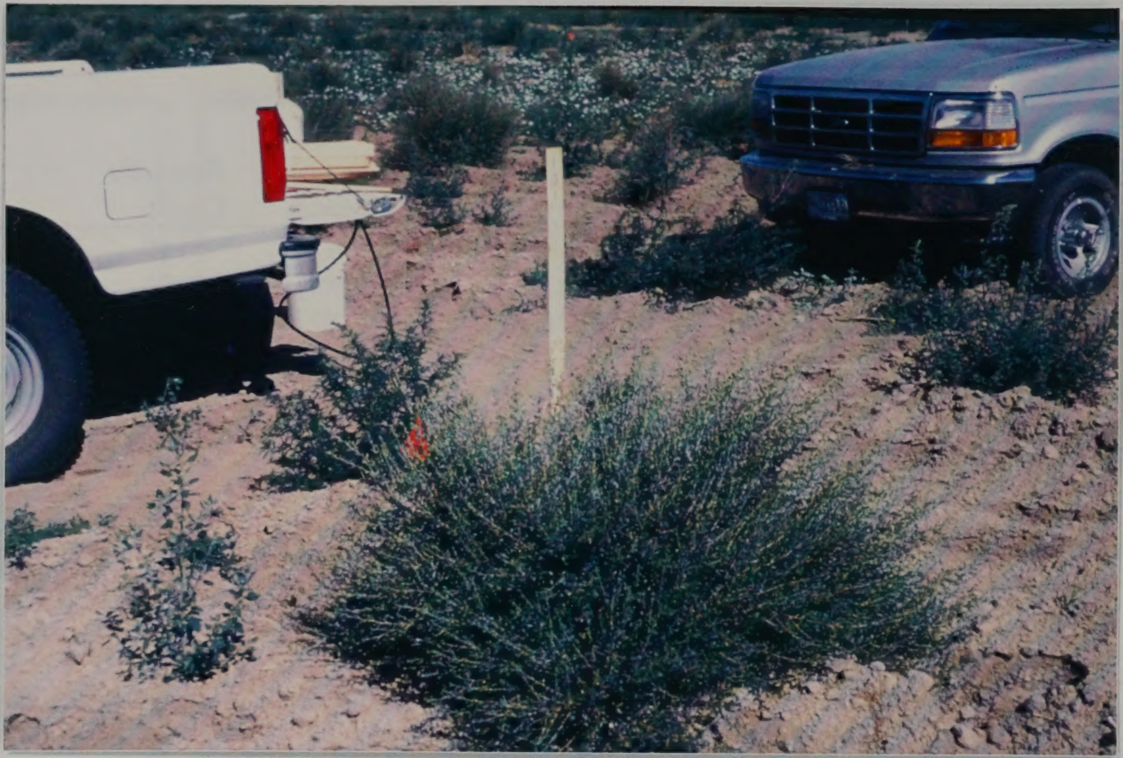


Figure 2. Three year old antelope bitterbrush interstrain cross plant before burning.

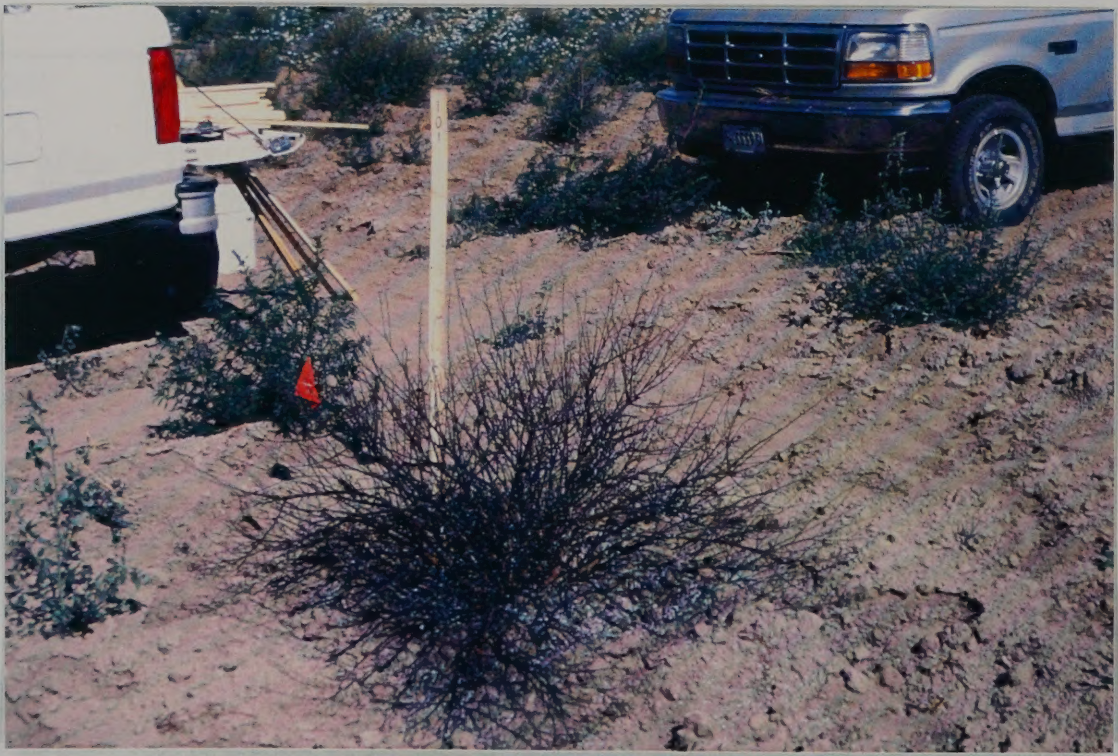


Figure 3. Antelope bitterbrush interstrain cross plant burned to test sprouting response.

Benefits of Greenstripping on the Mountain Home Air Force Base in Southern Idaho to Control Wildfires.

Stephen B. Monsen and Kelly L. Memmott

Introduction

The conversion of the semi-arid shrublands to an annual weedy community has altered the burning cycle of this ecosystem. Sites that may have burned every 50 to 100 years now regularly burns at a rate of 3 to 7 years. This fire cycle not only has degraded these ranges but facilitates the invasion and persistence of weedy exotics. Fire prevention and containment now cost a considerable amount of money each year.

Greenstripping is one way of containing and preventing fires. Recent studies have shown there are plants that can be planted at specific spacing to compete with weeds and serve as a greenstrip. The use of pre-emergent herbicides can be used to control weeds and allow the greenstrip plants to become established. Greenstrips of forage kochia and crested wheatgrass are being utilized by the Idaho BLM. There has been success with these plants but some improvements can be expected by adjusting plant density and alignment.

Study Objectives

The purpose of this study is to evaluate the usefulness of (forage kochia, crested wheatgrass, and Asiatic yarrow) when planted in separate but adjacent strips to prevent the spread of fire. Crested wheatgrass establishes well in these sites and maintains greenness longer than most annual grasses ie. cheatgrass. Forage kochia is a low growing shrub that adapts well to arid sites and provides lush growth throughout the growing season. Asiatic yarrow also stays green longer than most plants and is able to suppress annual weeds. Each species responds differently to burning and control of annual weeds.

In addition, movement of fire through pure stands of each species is different. Individual strips are being planted together to evaluate the benefits of using more than one species. This study has been established at the Mountain Home Air Force Base near Mountain Home, Idaho to demonstrate the potential benefits of this experiment.

Vegetative fuel strips will be compared to compare mechanical tillage which is now used at the base to control fire and provide fire breaks.

Methods

Crested wheatgrass, yarrow and forage kochia were each planted in separate plots that are 50x200 ft in size (see map). The perimeter was fenced leaving a 20 foot space on three sides of the plots and a 100 foot space on the west side of the plots. Annual grass will be planted in the 100 ft space adjacent to each plot. The strip of annual grass will be ignited and used to carry a fire into the test greenstrip plots. Forage kochia was planted as the last species in all four plots with yarrow and the crested wheatgrass alternating in order creating two reps of each order (see map).

Late in the fall of 1996 crested wheatgrass and forage kochia were drill seeded with 30 inch row spacings. Asiatic yarrow transplants were reared in a greenhouse in Provo, UT and field transplanted place during Feb 23-27, 1998. Plants were spaced at a distance of 30 inches. There were approximately 6,000 yarrow plants transplanted in the four plots.

Study plots will be maintained for approximately three years or until plants have attained mature status. At this time a fire line will be made around the perimeter and the western portion of the plots will be ignited. Fire spread, speed, and retardation will be recorded by the use of cameras and video equipment. Fire behavior including flame length, time elapsed, fuel consumption, and areas burned will also be recorded. Climatic data will also be recorded by the use of a portable weather station. Prior to burning, an assessment will be made on the composition and density of the plots. Moisture content of the plant species and the soil will also be gathered.

Results and Discussion

Results are not yet made as this study is in the establishment stage. It can be noted that the crested wheatgrass has established a good stand in all plots and the forage kochia has also began to establish well. The yarrow transplants should do well as they were transplanted at optimal conditions with good soil moisture and moderate humidity. Replanting will be done as deemed necessary for the success of the study. It will be necessary to monitor the plants and the fence perimeter to keep out the antelope that live in the area.

Management Implications

Management implications of this study are important to all concerned. A successful greenstrip could replace the need to constantly mechanically till areas which are costly, highly subjected to wind erosion, an eyesore, and not a permanent solution. Time will tell whether this combination of plants will be able to compete with the weedy exotic plants and deter the fires that are caused by the changed environment brought on by such weedy invaders.

Relevant Literature

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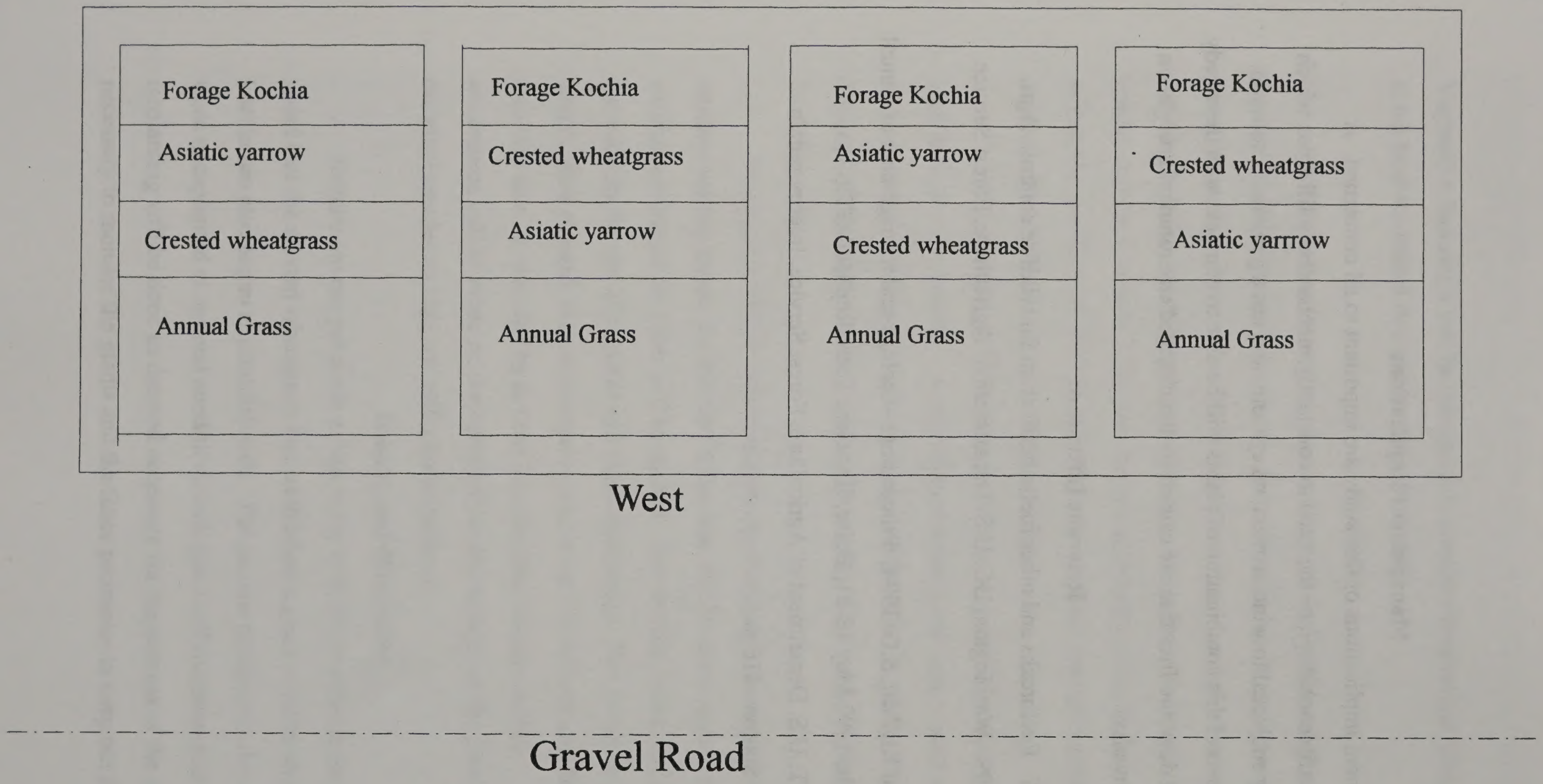


Mountain Home Greenstrip Planting Map

Seed Production of Squirreltail, Needle-and-thread Grass, Bluebunch Wheatgrass, Sandberg Bluegrass, and Thurbers Needle Grass

Stephen B. Monsen, Darren G. Naillon

Problem

Restoration of disturbed native communities is a major concern to western land managers. Demand for seed of many native grasses, particularly species existing in the sagebrush/bunchgrass communities far exceeds current supply. Cheatgrass (Bromus tectorum) and other annual weeds have invaded these communities creating frequent fires that further weaken and displace native shrubs and herbs. Reestablishment of native species is essential to replace and control the spread of alien weeds, contain fires, and restore resource values. Wildfires occurring throughout the foothill communities continue to increase dramatically. Approximately 750,000 acres of rangeland burned in Idaho in 1996, and approximately 350,000 acres burned in Utah during the same period. The average number of fires and the total area burned each year has continued to increase throughout the Intermountain Region for the past 20 to 30 years. Attempts to seed these disturbances and restore native species is restricted because of insufficient suitable seed.

Seeds of most native species are collected from wildland sites which is slow, laborious, costly, and often does not provide sufficient quantities for seeding needs. Seeds of some species are being produced under intensive cultivation but proper rearing techniques have not been fully developed for all species. Seeds of Sandberg bluegrass (Poa secunda), bottlebrush squirreltail (Elymus elymoides), bluebunch wheatgrass (Psuedoroegneria spicata [Pursh] Love), Thurbers needlegrass (Stipa thurberiana), and needle-and-thread grass (Stipa comata) are important species in these communities.

Although limited amounts and varieties of bluebunch wheatgrass and Sandberg bluegrass is grown under cultivation, the effects of seed production and harvesting on seed quality is not fully understood. The other three grasses are not grown under cultivation and each present some problem related to seed production and harvesting.

A cooperative project was developed between the USDA, Forest Service, Rocky

Mountain Research Station, Shrub Sciences Laboratory, Provo, UT; Utah Division of Wildlife Resources at Great Basin Research Center, Ephraim, UT; Utah Crop Improvement Association, Logan, UT; with principal funding from Utah Agricultural Experiment Station of Utah State University, Logan, UT. Studies were initiated to: 1) Evaluate and develop procedures to harvest seed from some grasses with indeterminate flowering and seed ripening, species with a disarticulating rachis and from species with seeds and floral parts that produce extended awns and related appendages. 2) Investigate the effects of plant spacing, fertilization, and irrigation upon seed production and seed quality of these principal grasses currently in demand.

Methods

Utah Division of Wildlife Resources (DWR) has removed from production approximately 13 acres of farmland to provide areas to organize and establish two studies. Irrigation pipe and sprinklers have been repaired and provided to irrigate both sites. Existing pressurized water lines have been modified to accommodate irrigation of small plots. Arrangements have been made with the DWR and Shrub Sciences Lab to provide vehicles and farm equipment to maintain fields, control weeds, irrigate and fertilize the study plots.

This is an excellent seed rearing site and will be used to support various plant releases within the near future. Asiatic yarrow has been transplanted to this site to establish a seed increase field in preparation for release. The Division of Wildlife Resources is also growing other grasses for seed increase. The agreement with Utah State University supports studies with two species. Funds received from Idaho BLM allow us to expand efforts to include additional plant materials.

Seed Harvesting Studies (Study 1)

Seed production fields were established of five species of grasses at the Fountain Green Wildlife Management area owned and managed by the Utah Division of Wildlife Resources. The site is located near Fountain Green, Sanpete County, Utah. The planting site was fallowed throughout the summer of 1996. Fields were disked and sprayed during this time to remove and control weeds. Seed production fields were established by drill seeding in November 1996 with John Deere Flex planters. Grass species planted were:

Bluebunch wheatgrass, Sandberg bluegrass, needle-and-thread grass, Thurbers needle grass and bottlebrush squirreltail. Seeds of each species were hand collected from specific wildland sites or populations that have been under study for restoration purposes. Approximately one acre was drill seeded for each of the five species of grasses. Seeds production fields were established to evaluate: 1) The effects of rearing practices upon seed production and seed quality. 2) The capabilities of different types of equipment to harvest seeds, minimize loss from harvesting and natural shattering, and minimize seed damage.

Fields planted in 1996 will be maintained until plants reach maturity and begin to produce seed. At this time, seed rearing practices including amounts and timing of irrigation upon seed production and seed ripening will be evaluated. The fields will also be used to evaluate the capabilities of different harvesting equipment, principally conventional combines and front-mounted reel sweeps to dislodge and remove mature seeds. Sweeps will be evaluated to harvest the same stands at 2-3 dates as seeds mature. Repeated harvesting will be evaluated to determine success in harvesting all seeds, maximizing seed quality, and determining the impacts upon live plants.

Seed Culture (Study 2)

This study has been designed to investigate the influence of different plant spacings, irrigation, fertilization and combinations of these treatments on seed production and seed quality. The grass species selected for this study were; needle-and-thread grass, Sandberg bluegrass, and bottlebrush squirreltail. Transplants of each species were propagated under green house conditions at the Shrub Sciences Laboratory from Dec. 1996 to Feb. 1997. Transplanting was completed in mid April as fields became accessible. Each species was planted in four replicated blocks to measure the effects of different plant spacings, supplemental irrigation, and moderate levels of fertilizer. Each replicated plot consists of 49 individual plants. Seedlings were planted in blocks of 12, 18 and 30 inch spacing. As plants attain maturity, 10 individuals will be randomly selected and monitored to determine time of flowering and seed maturation. In addition, seeds will be harvested from each of the 10 plants and cleaned to determine number of seeds per plant, seed size, seed weight, and viability.

Results and Discussion

Studies are currently underway and should yield preliminary results in summer and fall of 1998. Transplants have established well. Sandberg bluegrass will need to be drilled again in spring of 1998 to achieve a more uniform stand. Figure 1 displays the layout of the study site. Figures 2 and 3 illustrate the alignment of plots and treatments for the seed culture study.

Management Implications

Development of propagation techniques and release of selected ecotypes will provide land managers additional resources when planning restoration and revegetation projects. Native species are especially in high demand as the public increases pressure to plant natives. This study will assist growers to economical produce these plant materials and make them available on the market to land managers.

Technology Transfer Products

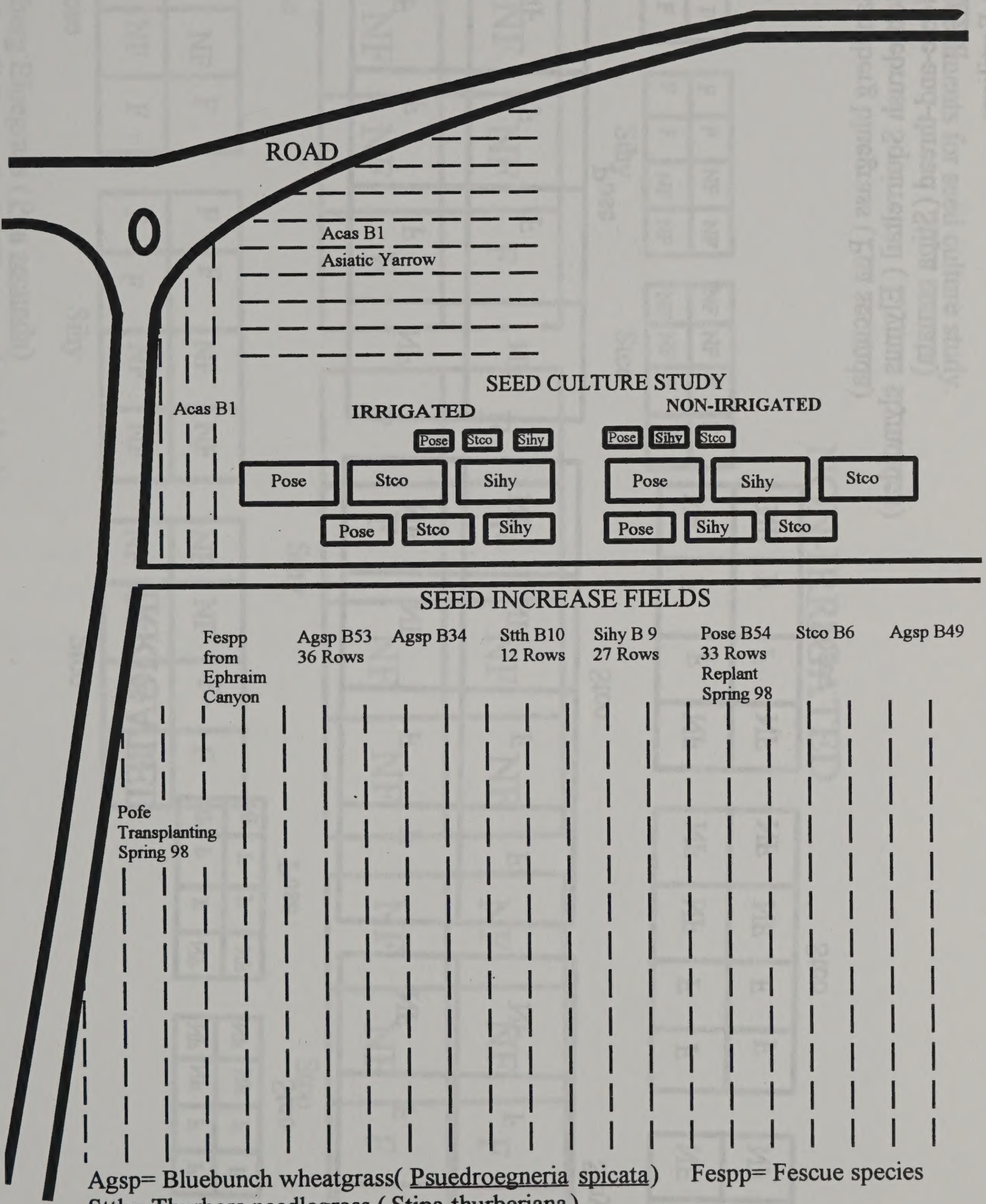
Plant Materials

This research will enable the release of selected ecotypes of bluebunch wheatgrass, Thurbers needle grass, Sandberg bluegrass, and squirreltail. These ecotypes are intended for use in southern Idaho and provide needed germplasm not presently available to land managers. The Division of Wildlife Resources will release the mutton grass and needle-and-thread grass for use within the Great Basin.

Propagation Techniques

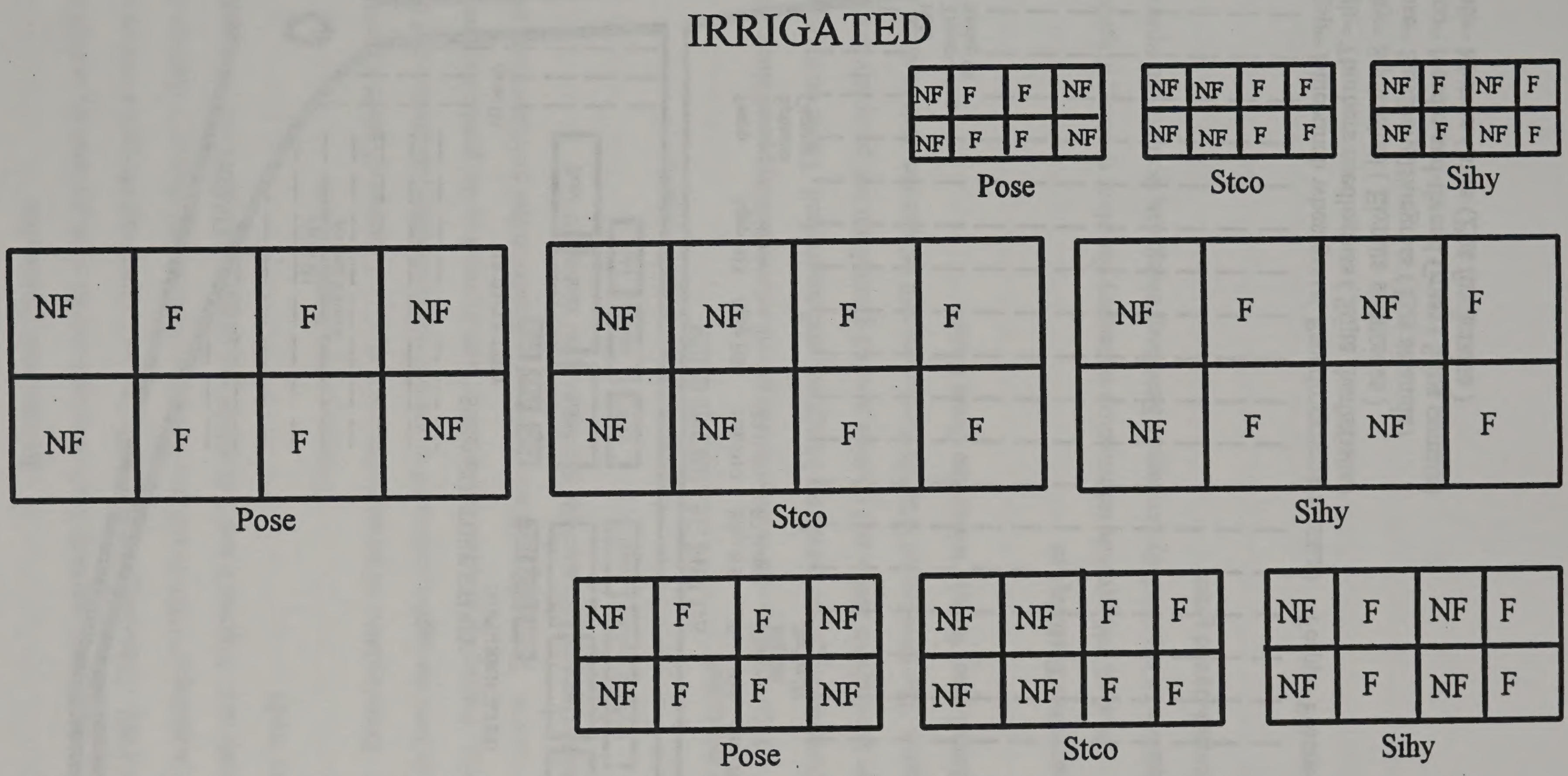
Study 2 will provide information necessary for plant spacing, irrigation and fertilization to successfully propagate Sandberg bluegrass, bottlebrush squirreltail, and needle-and-thread grass.

Figure 1. Fountain Green seed increase and Culture Study planting map.



Agsp= Bluebunch wheatgrass(Psuedroegneria spicata) Fespp= Fescue species
Stth= Thurbers needlegrass (Stipa thurberiana)
Sihy= Squirreltail (Elymus elymoides)
Pose= Sandberg Bluegrass (Poa secunda)
Stco= Needle-and-thread Grass (Stipa comata)
Pofe= Mutton Grass (Poa fendleraina)

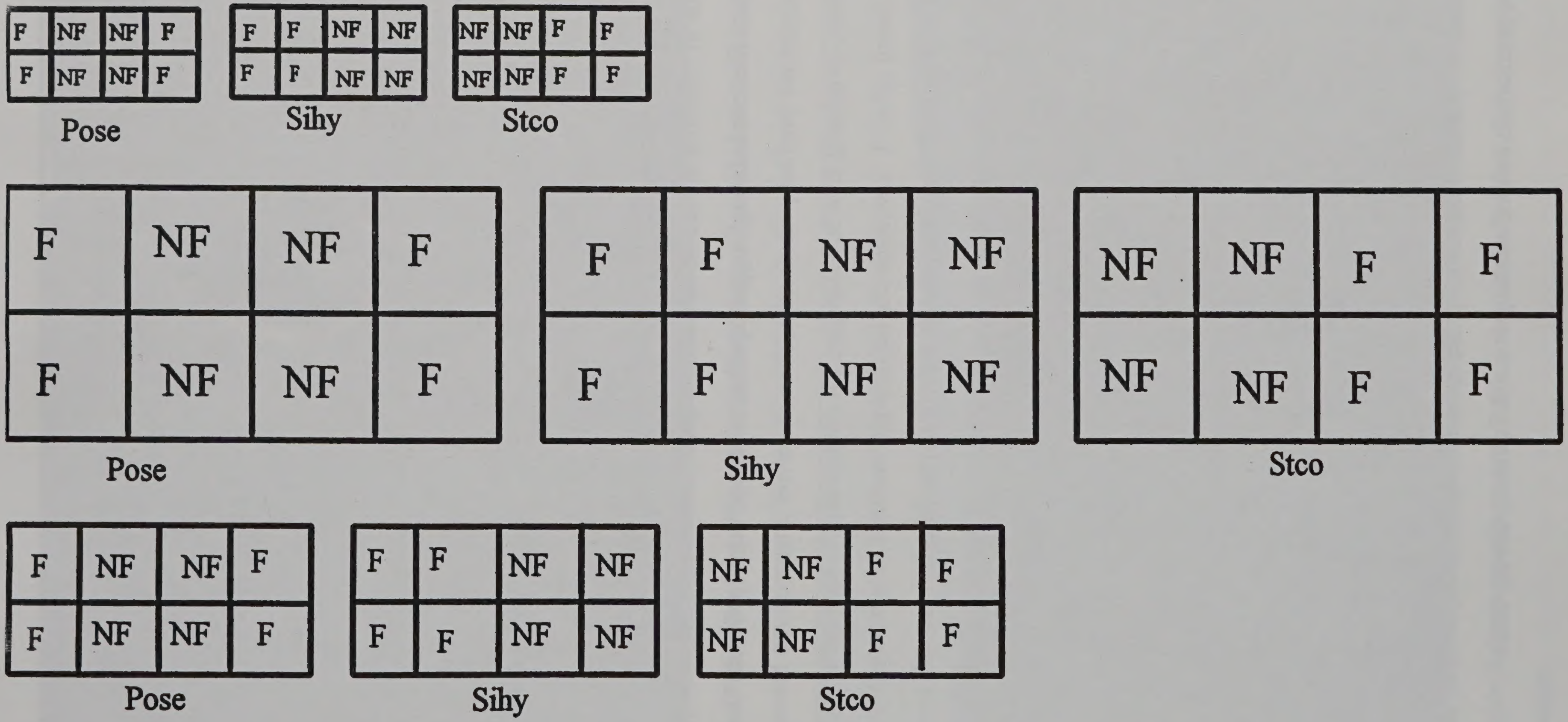
Figure 2. Treatments for seed culture study.



Pose=Sandberg bluegrass (Poa secunda)
Sihy=Bottlebrush Squirreltail (Elymus elymoides)
Stco=Neele-and-thread (Stipa comata)
F=Fertilized
NF=No Fertilizer

Figure 3. Treatments for seed culture study.

NON-IRRIGATED



F	NF	NF	F
F	NF	NF	F

Pose

F	F	NF	NF
F	F	NF	NF

Sihy

NF	NF	F	F
NF	NF	F	F

Stco

F	NF	NF	F
F	NF	NF	F

Pose

F	F	NF	NF
F	F	NF	NF

Sihy

NF	NF	F	F
NF	NF	F	F

Stco

F	NF	NF	F
F	NF	NF	F

Pose

F	F	NF	NF
F	F	NF	NF

Sihy

NF	NF	F	F
NF	NF	F	F

Stco

Pose=Sandberg Bluegrass (Poa secunda)
Sihy=Bottlebrush Squirreltail (Elymus elymoides)
Stco=Needle-and-thread (Stipa comata)
F= Fertilized
NF=No fertilizer

Figure 4. Richard Stevens kneeling in grass spacing study at Fountain Green, Utah.

Figure 5. Seed production field of asiatic yarrow at Fountain Green, Utah.

Thurber Needlegrass and Bottlebrush Squirreltail Seed Production as Affected by Field Rearing Practices

Stanley G. Kitchen, Loren St. John, and Stephen B. Monsen

Introduction

To be successfully included in revegetation projects, seed must be available at an affordable cost. For many desirable species, wildland seed production is inadequate, of low quality, and/or too difficult to collect to expect to meet commercial seed demands at affordable prices. For some of these species, seed needs are best met by employing conventional agronomic methods to grow and harvest seeds in a semi-controlled setting. However, not all species lend themselves easily to agronomic practices. For example, uniform stand establishment using dormant seeds can be difficult. In addition, innate characteristics such as indeterminate flowering and rapid seed shattering may be adaptive in a natural environment, however, such traits create problems for maximizing yields from field plantings. Furthermore, the responses of wild species to conventional practices such as irrigation and fertilizer application are unknown. Finally, insect and disease problems that are insignificant in diverse natural settings often explode in well kept monocultures.

Thurber needlegrass (Stipa thurberiana) and bottlebrush squirreltail (Elymus elymoides) are bunchgrasses native to semi-arid rangelands in the western United States. Thurber needlegrass has not been used in restoration/revegetation projects due primarily to low seed availability. Wildland collections for this species are generally impractical due to low production, indeterminate maturation, rapid seed dispersal, and lack of wild populations suitable for mass collection. Due to cost and low seed supply, bottlebrush squirreltail seeds are only used to a limited extent in restoration/revegetation projects. Although bottlebrush squirreltail seed production is relatively good under favorable conditions, a disarticulating rachis and long (2-12 cm) awns on seeds and glumes make seed harvest and processing for this species problematic. Limited efforts in field cultivation have not yet met with sufficient success to have altered market conditions for this species.

Objectives

We have two objectives in this study. First, we are examining the influence of irrigation and fertilizer treatments on the quantity and uniformity of seed production for Thurber needlegrass, and bottlebrush squirreltail. Second, we are investigating the effect of harvest timing on seed yield and quality.

Methods

Seed rearing blocks of Thurber needlegrass and bottlebrush squirreltail were established at the Aberdeen Plant Materials Center in 1995 in a cooperative effort between the Natural Resource Conservation Service and Forest Service, Rocky Mountain Research Station, Shrub Sciences Laboratory. Greenhouse-reared transplants were arranged in blocks; each block consisting of 5 rows (1.2 m. spacing) of 10 plants each (0.3 m. spacing). A randomized block design was employed for each species with five replications of each irrigation/fertilization treatment combination. Treatments included control (no irrigation or fertilization), irrigation alone, fertilization alone, and irrigation and fertilization combined. Irrigation (approximately 10 cm) was applied periodically through the summer of 1995, 4 June and 3 August 1996, and 19 May 1997. Fertilization treatments of 34-0-0 analysis at 169.2 kg/ha and 11-52-0 analysis at 80.1 kg/ha were applied in the summer of 1995 and again on 15 May 1997. Weeds were controlled by hand weeding and fall applications of Surflan (pre-emergent).

Transplant survival was assessed on 14 August 1995 and again on 10 April 1996 (table 1). Plants were rated for vigor on a scale of 1 (best) to 9 (dead) on 13 May 1996. Due to higher than expected first-year mortality and high within-plot variability for plant vigor, the study design was altered so that individual plants would serve as replicates. Approximately 40 plants of relatively high vigor were selected from each species/treatment combination (160 of each species).

For each species, seeds were hand collected from 10 selected plants per treatment combination (40 total) on each of three harvest dates. In 1996, Thurber needlegrass seeds were collected on 26 and 28 June and 2 July, and bottlebrush squirreltail seeds were collected on 2, 5, and 8 July. A total of 120 collections were made for each species. Seeds from individual plants were placed in labeled paper sacks, air-dried, and stored for laboratory processing. The same plants were recollected in 1997 with minimal substitution. Collection dates for both species in 1997 were 24 and 27 June and 1 July.

Each 1996 collection of Thurber needlegrass was cleaned to remove empty fruits and inert material, weighed, and counted. Laboratory germination experiments were conducted to assess among-treatment differences in seed viability and dormancy. Results have not yet been analyzed. Laboratory work on 1997 Thurber needlegrass collections is in progress. Processing of 1996 bottlebrush squirreltail collections has been completed. Results have not yet been tabulated and collections made in 1997 have not been processed.

Two 24.4 m. rows of bottlebrush squirreltail and Thurber needlegrass were drilled on 29 May 1997 to assess direct seeding success and better estimate seed yield from drilled rows. Plots were irrigated in June, July, September, and October. Due to competition from cheatgrass (present in the seed), 'Oust' treatments will also be evaluated on these plantings.

Results and Discussion

At this point seed yield and quality results must be considered preliminary and used with caution. Mean seed weight for 1996 Thurber needlegrass collections was 2.9 mg and was highly uniform for all treatments and harvest dates. This suggests that seed size is under tight genetic control. Total seed number per plant was greatest for irrigation treatments (table 2). Fertilization treatment had no significant effect. Plants in the irrigation/fertilizer treatment had lower seed counts than did those in the irrigation only treatment. This is likely due to greater competition from weeds.

Plants were generally larger in 1997 than 1996 with corresponding higher seed yields. There were, however, notable exceptions. Field examination of low vigor and dead plants revealed poor root development outside of the transplanted soil plug. Transplants were somewhat root-bound when planted and some failed to develop normal root systems. This was especially true for Thurber needlegrass. This was probably the cause of the higher than expected first-year mortality (table 1) and the high variability in plant vigor that we observed. More accurate yield estimates will be available from the drilled plots as these stands mature.

Management Implications

Preliminary results (based on dry seed wts) suggest that seeds of both of these species may be harvested as much as a week before shattering begins without compromising yield or seed quality. This would provide a broader window of opportunity to complete harvest operations. This conclusion will certainly be more refined after careful analysis of the data generated by this multi-year study.

This study was designed to last for a minimum of 4 to 5 years. The meaning of results and accuracy of interpretations can not be properly assessed in a shorter time frame. Therefore, the value of this study is linked to consistency in funding support.

Table 1. Thurber needlegrass and bottlebrush squirreltail transplant survival (1996) at the Aberdeen Plant Materials Center.

Species	Treatment	14 Aug 1995	10 Apr 1996
		---Survival Percentage---	
Thurber needlegrass	Control	66	56
	Irrigation	83	74
	Fertilization	52	51
	Irrigation + Fertilization	75	70
Bottlebrush squirreltail	Control	75	60
	Irrigation	87	63
	Fertilization	66	58
	Irrigation + Fertilization	73	52

Table 2. First year individual plant seed production for Thurber needlegrass at the Aberdeen PMC.

	Treatment				
Collection Date	Control	Irrigation	Fertilizer	Fert. & Irr.	Mean
	-------------------- Number of Seeds per Plant -------------------				
26 June	117	350	180	114	190
28 June	208	370	119	192	222
2 July	168	271	133	96	167
mean	164	330	144	134	193

Effects of Anchor Chaining on Seedling Establishment and Water Repellent Soil Conditions

Stephen B. Monsen, Darren G. Naillon

Problem

Restoring steep rough terrain to acceptable condition and preventing the invasion of weeds is a challenge to land managers. The Boise Foothills fire of 1992 created considerable concern regarding the potential loss of watershed and wildlife resources. Vegetation was removed from steep granitic slopes where extensive erosion and runoff could occur. In most situations plant recovery could be expected, although some woody and herbaceous species are not fire tolerant. Prior to burning some sites supported an understory of cheatgrass (Bromus tectorum) with few remaining natives. Unless seeded these sites could quickly be dominated by cheatgrass.

It has become common practice in restoring rangelands to broadcast seed steep slopes not suitable for drill seeding. Seed is not covered or incorporated into the soil and poor seeding success otfen occurs. Broadcast seeding usually produces erratic establishment in most rangeland seedings unless some method is used to cover the seed. Seeds of many species do not establish unless they are incorporated into the soil or are covered with litter. Establishment of many desirable species cannot be achieved without some means to create better seedbeds.

Chaining is commonly used to prepare seedbeds and facilitate seeding in big sagebrush and pinyon-juniper types. Anchor chaining has also been used in other regions to create a seedbed and plant steep irregular slopes. The technique has proved practical, for covering seeds and providing enough surface tillage which actually reduces erosion (Farmer 1995). Tillage created by chaining appears to be a useful technique to accommodate seedbed preparation and modify or reduce water repellent soil conditions. This technique has not been employed on the granitic soils in the foothills of south central Idaho. The amount of soil surface tilled and depth can be easily regulated by chain weight and other special modifications.

Sites that were burned create considerable hazard to runoff and erosion as soils develop a water repellent or non-wettable condition. This is a result as volatilization of plant chemicals during burning leaves wax deposits in the soil. The wax forms impervious layers within the soil profile that reduce infiltration causing runoff and erosion. Granitic soils of the Idaho batholith creates a particularly serious erosion problem. These soils are naturally quite erodible and any disturbance to the vegetation or soil structure can create serious erosion and damage to downstream resources. Attempts have been made to till soil surfaces to break-up the water repellent conditions. Other test have added compounds to break-up the wax layers. These efforts have proved too expensive or limited in sites that they can be applied. Physical tillage of soil has been effective while high cost are associated with this technique.

The goals of this study were two fold: 1) evaluate reduction of water repellent characteristics of the soil by tillage and 2) evaluate the effects of anchor chaining on plant recovery and establishment of seeded species on steep slopes. Studies were established within sites previously occupied by antelope bitterbrush (Purshia tridentata), mountain big sagebrush (Artemesia tridentata ssp. vaseyena), and bluebunch wheatgrass (Agropyron spicatum).

Methods

In the fall of 1992, following a burning of the area, eight small watersheds were selected for study in the Dry Creek drainage. Four south facing slopes and four north facing slopes were selected. The eight small watersheds collectively comprise a small drainage about 60 acres is size. Slopes were consistently 40 percent in all watersheds. Watersheds were aerially seeded in November 1992. A mixture of grasses, broadleaf forbs, and shrubs were commonly seeded. Immediately following seeding two north and two south aspect watersheds were anchor chained. Chaining was conducted using two D-7 caterpillars and a 30 pound link smooth chain. This set in place four paired plots of chained and non-chained slopes to provide a comparison of this treatment on the establishment of seeded species and the influence of surface disturbance on reducing water repellency.

Soils in the watersheds were inventoried following the treatments to determine the percent of area with water repellent soils. Depths of water repellent layers and relationship of soil conditions to water repellency was recorded. Sites were inventoried again in summer 1993, 1994 and 1995 to determine changes in soil conditions of chained and non-chained treatments.

Four transects parallel to each slope were established to inventory herbaceous growth of seeded and native species on each treated site. Ten m^2 frames were randomly placed along each transect to sample vegetative growth. A total of 40 sample frames were taken in each watershed. Data were recorded in summer 1993, 1994, and 1995.

Results and Discussion

This study demonstrated anchor chaining could be easily managed and caterpillars and chain could be collectively operated on the steep slopes. Sufficient areas were treated to evaluate the ability of the units to transverse up and down the slopes as well as contouring the slopes. The effect of the chaining operation on surface tillage and disruption to remaining plants was noted. Concern was expressed that the chain would be too destructive to both soil stability and plant recovery. This did not occur. Both the catepillars and chain could be operated on the slopes without excessive disturbance. The degree of soil tillage could be regulated by speed and position of the chain. Little or no tillage occured when the cats operated side-by-side. If one cat operated forward or in front of the other a long narrow loop was created in the chain which increased surface tillage. Tillage can also be regulated by weight of chain and configuration of disk or bars welded across the chain. Chaining was demonstrated to be functional and easily regulate tillage on steep slopes. The technique can effectively treat large areas with much less cost than other seedbed tillage equipment.

Studies revealed that chaining had less effect on reducing soil water repellent conditions than anticipated. Immediately following burning between 60 and 70% of all soils were water repellent (figure 1). One year after burning water repellent soils in all watersheds decreased 35 to 40% with the exception of one chained north aspect (figure 1). Figure 2 shows the depth of water repellent layers. In 1992 the soil surface had a large number of samples that were non-wettable. By 1994 the soil surface was largely permeable with no water repellent layer. Below the surface, water repellent layers remained relatively constant across all years despite chaining treatments (figure 2).

Chaining was influenced by the condition of the soil surface. Generally chaining was effective in reducing water repellent conditions in open sites or areas void of perennial grass clumps. In watershed six, a north aspect that was chained, no difference in water repellent soils was recorded after chaining. Perennial grass dominated the ground cover. By comparison, watershed seven displayed the opposite effect. After chaining the water repellency decreased from 88 percent to 44 percent. This can be attributed to a lack of perennial grass cover. Grass crowns in watershed six did not allow the chain to effectively till the soil. It appears more surface tillage would be required to reduce the water repellent nature of the soil where heavy perennial grass cover existed prior to wildfire than was created by the 30 pound link smooth chain. This could be accomplished with slight modifications to the chain and the operation of the caterpillars.

The beneficial effects of chaining on seedbed preparation, seedling establishment and water repellent soils was supported by this study. From information presented in tables and figures the following conclusions can be made.

1) This study demonstrates that chaining increased the number antelope bitterbrush seedlings to initially establish and persist through 1995. Without chaining no antelope bitterbrush seedlings established on south facing slopes (table 1). By comparison, approximately 1,800 antelope bitterbrush seedlings per acre were recorded on the chained south slopes in 1993. Numbers decreased to 200 seedlings per acre in 1994 and 1995 on chained south slopes. Non-chained south slopes recorded 40 plants per acre in 1994 and 1995. Two hundred plants per acre is adequate for reestablishment of desired stands. Some seedlings of antelope bitterbrush were able to establish on north slopes without chaining. Sufficient soil accumulation and entrapment of seeds by grass crowns provided a suitable seedbed. However, nearly all antelope bitterbrush seedlings that initially established on the non-chained north slope succumbed in 1994. Losses were due to competition from recovering native grasses. Non-chained slopes had limited success in establishing antelope bitterbrush. Chaining more than doubled the number of antelope bitterbrush seedlings to establish on north slopes. Nearly 70% of all antelope bitterbrush seedlings that appeared in 1993 on the chained north slopes persisted through 1995. Differences in number of seedlings on chained and non-chained north slopes is due in part to the competitive presence of perennial grasses. Seedlings were much more

dispersed and were not so concentrated near crowns of native grasses on chained slopes. Seeding antelope bitterbrush on north aspects where snow accumulation will likely occur increases the chance of establishment, but surface seeding without some soil coverage is not advised. Previous research indicates that delaying seeding until late fall or early winter is advisable to lessen depredation by rodents. It must also be noted that bitterbrush seeds require a cold stratification to enhance germination so delaying seeding until spring is not advised. Antelope bitterbrush in chained areas were less subjected to competition, and exhibited higher establishment and survival percentages.

2) Chaining resulted in greater numbers of big sagebrush seedlings to initially establish in 1993 and persist through 1995 on all sites (table 2). Chaining resulted in over four times more seedlings on both north and south aspects than on non-chained slopes. Greater numbers of seedlings established on south aspects than on north aspects as more open sites occurred. The number of big sagebrush seedlings declined on all sites between 1993 and 1995. Approximately 1,760 plants per acre were recorded on non-chained north aspects in 1995, a decrease of approximately 64% from the 1993 counts. The number of plants recorded for chained north sites in 1995 was 5,560 plants per acre. This is a reduction of 70% from plants recorded in 1993. Nearly 5,000 plants per acre were recorded for non-chained south aspects in 1995, a reduction from initial figures of only 20%. Chained south slopes supported over 11,000 plants per acre in 1995 a decrease of 48% of all seedlings that were recorded in 1993. A sufficient number of big sagebrush plants have survived through 1995 to provide a dense stand in all treatments. Chaining did result in considerably more big sagebrush seedlings, surface tillage is not necessary to establish adequate sagebrush density. Big sagebrush plants have been successfully established by broadcast seeding in many other wildland sites throughout the Intermountain region, and this technique should be used to reestablish this species on sites in southern Idaho. Aerial seeding of sagebrush can be successfully accomplished by late fall and winter seeding, particularly if seeds are deposited on a snow cover or rough surface. Areas seeded did receive a deep snow cover which ensured shrub seedling establishment. By seeding prior to snow fall or on a snow cover, seedlings are more likely to establish.

3) Chaining did not diminish or disrupt the recovery of native perennial grasses or broadleaf herbs. No difference was recorded in the percent ground cover or frequency occurrence of bluebunch wheatgrass, cheatgrass, Sandberg bluegrass (Poa secunda), bottlebrush squirreltail (Elymus elymoides), silvery lupine (Lupinus argenteus), nine leaf lomatium (Lomatium triternatum ssp. platycarpum) or arrowleaf balsamroot (Balsamoriza sagittata) in chained and non-chained sites in 1993 (tables 4 and 5). A slight decrease in cover of Hoods phlox (Phlox hoodii ssp. canescens) was recorded in chained sites in 1993. This is a surface creeping species and could be easily uprooted with minimal tillage. This species is not a concern as it recovers and spreads in years following the chaining. Chaining did not adversely affect percent cover of any native bunchgrass (table 3). Percent cover for Sandberg bluegrass and bluebunch wheatgrass were not significantly different from one another in chained and non-chained slopes. The native perennial grasses recovered from the fire and the physical action of the chain did not seriously uproot or damage grass crowns.

4) Chaining increased the establishment of seeded grasses (table 3). Chaining not only increased the number of seedlings to establish but plant distribution and uniformity of occurrence was greatly increased. Percent ground cover of seeded grasses were similar on chained and non-chained north slopes and chained south slopes in 1993 and 1994. Non-chained south slopes had few seeded grasses establish on them because of not incorporating seed into soil combined with sun drying on south slopes. Chaining incorporates the seed into the soil where conditions are more favorable for establishment. The number of seeded grasses increased from one plant per m^2 on non-chained south slopes to 16 plants per m^2 on chained south slopes. The same effect was not observed on north slopes and may be attributed to more favorable moisture conditions decreasing the impact of chaining on these sites. By 1995 seeded grasses persisted on north slopes more than south slopes. This would be expected as north slopes generally produce more biomass than south slopes due to favorable water conditions.

5) Chaining did change soil surface or seedbed conditions, which diminished seedling establishment and subsequent growth of some weedy species. Chaining decreased the ground cover of bulbous bluegrass and cheatgrass, particularly on the south aspects. Small seeded species of both Sandberg bluegrass and bulbous bluegrass do not

require surface disturbance to establish. Cheatgrass did not benefit from chaining, particularly on south slopes where openings were common. Although cheatgrass seeds are large, surface disturbances were not required to plant seeds of this species. Chaining significantly decreased cheatgrass cover from 1993 to 1995 on south slopes. The beneficial advantages of chaining for establishing desired seeded species is complimented by the decrease in density and cover of weedy species. Chaining is definitely a useful technique to assure seedling establishment and quickly reestablish desired communities.

6) Chaining was essential to the establishment of both small burnet (Sanguisorba minor) and alfalfa (Medicago sativa). Without chaining almost no plants of these species established on either north or south slopes. In comparison, on chained south slopes six plants per m^2 of alfalfa and 12 plants per m^2 of small burnet established (table 4). On north slopes a similar effect was observed with four plants per m^2 of alfalfa and small burnet species growing. Chaining helped incorporate these seeds into the soil which is necessary for their establishment.

Management Implications

This study has shown that chaining is a viable option to land manager in restoring rangelands to incorporate seed into the soil increasing seeding success. Chaining does not adversely effect the native community as it generally will recover following the treatment. Various options of chain size and chain configuration can be used to reduce water repellent soil conditions and diminsh erosion.

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Farmer, M. E. 1995 The effects of anchor chaining pinyon-juniper woodland on watershed values and big game animals in central Utah. Master Thesis, BrighamYoung University, Provo, UT.

Table 1. Average number of antelope bitterbrush plants to occur on chained and non-chained south and north aspects.

	TREATMENTS			
	NORTH ASPECTS		SOUTH ASPECTS	
Years	Non-Chained slopes	Chained slopes	Non-Chained slopes	Chained slopes
1993	240	520	--	1800
1994	--	--	40	200
1995	40	360	40	200

Table 2. Average number of mountain big sagebrush plants per acre to occur on chained and non-chained south and north aspects.

	TREATMENTS			
	NORTH ASPECTS		SOUTH ASPECTS	
Years	Non-chained slopes	Chained slopes	Non-Chained slopes	Chained slopes
1993	4,920	18,360	6,160	26,120
1994	3,760	13,720	3,440	30,400
1995	1,760	5,560	4,920	11,120

Table 3. Percent ground cover for selected species and for chained and non-chained south and north aspects, 1993 through 1995.

Treatments	SPECIES					
Non-Chained North Slopes					**Percent Cover**	
	Sandberg Bluegrass	Bluebunch wheatgrass	Idaho Fescue	Seeded Grasses	Cheatgrass	Bulbous bluegrass
1993	5.11	4.56	2.16	1.01	0.50	0.56
1994	8.81	5.76	6.59	9.09	0.30	0.74
1995	2.51	6.73	6.28	14.16	0.83	0.19
Chained North Slopes						
1993	3.45	3.35	0.99	1.43	1.70	0.75
1994	8.49	4.20	7.64	10.58	0.15	0.09
1995	4.66	3.35	2.89	10.19	0.69	0.24
Non-Chained South Slopes						
1993	1.77	1.78	0.00	0.59	2.49	6.75
1994	5.04	3.23	0.00	1.66	5.13	2.23
1995	3.14	4.60	0.03	1.08	9.21	1.20
Chained South Slopes						
1993	2.47	3.12	0.00	2.71	0.89	1.88
1994	4.80	7.10	0.00	10.04	0.54	1.07
1995	2.13	7.20	0.03	3.83	0.81	0.59

Table 4. Number of plants/m^2 and frequency of occurrence for nonchained and chained **south** slopes in 1993.

Species	Nonchained Frequency	Nonchained Density (Plants/m^2)	Chained Frequency	Chained Density (Plants/m^2)
Bluebunch wheatgrass	43.8	2.5	57.9	5.6
Sandberg bluegrass	76.3	4.8	91.3	7.8
Squirreltail	2.5	0.1	1.3	0.1
Bulbous bluegrass	58.7	10.5	41.3	3.1
Cheatgrass	55.0	2.8	66.0	2.8
Crested wheatgrass	36.3	1.1	88.8	16.0
Cryptantha	100.0	17.6	97.5	27.6
Silvery lupine	17.5	0.2	17.5	0.2
Nine-leaf lomatium	12.5	0.2	18.8	0.3
Arrowleaf balsamroot	5.0	0.1	42.5	0.7
Long-leaf phlox	46.3	2.5	33.8	1.1
Small burnet	11.2	0.1	100.0	12.5
Alfalfa	10.0	0.1	99.0	6.3
Big sagebrush	55.0	1.5	90.0	7.5
Bitterbrush	----	----	30.0	0.5

Table 5. Number of plants/m^2 and frequency of occurrence for nonchained and chained **north** slopes in 1993.

Species	Nonchained		Chained	
	Frequency	Density (Plants/m^2)	Frequency	Density (Plants/m^2)
Bluebunch wheatgrass	86.3	8.2	78.8	7.3
Sandberg bluegrass	77.5	13.2	73.8	8.9
Idaho fescue	51.3	3.9	37.5	2.3
Bulbous bluegrass	20.0	0.9	27.5	2.1
Cheatgrass	36.3	0.9	57.5	2.8
Crested wheatgrass	38.7	3.8	57.5	3.5
Cryptantha	60.3	17.4	82.5	12.3
Silvery lupine	31.3	0.5	65.0	1.9
Nine-leaf lomatium	23.8	0.6	48.7	1.1
Arrowleaf balsamroot	38.8	0.6	27.5	0.5
Long-leaf phlox	57.5	2.4	40.0	2.3
Small burnet	15.0	0.2	83.8	4.2
Alfalfa	1.2	0.1	87.5	4.7
Big sagebrush	67.5	1.7	83.8	3.8
Bitterbrush	6.3	0.1	14.2	0.2

Figure 1. Percent non-wettable soils for chained and non-chained aspects in 1992 and 1993.

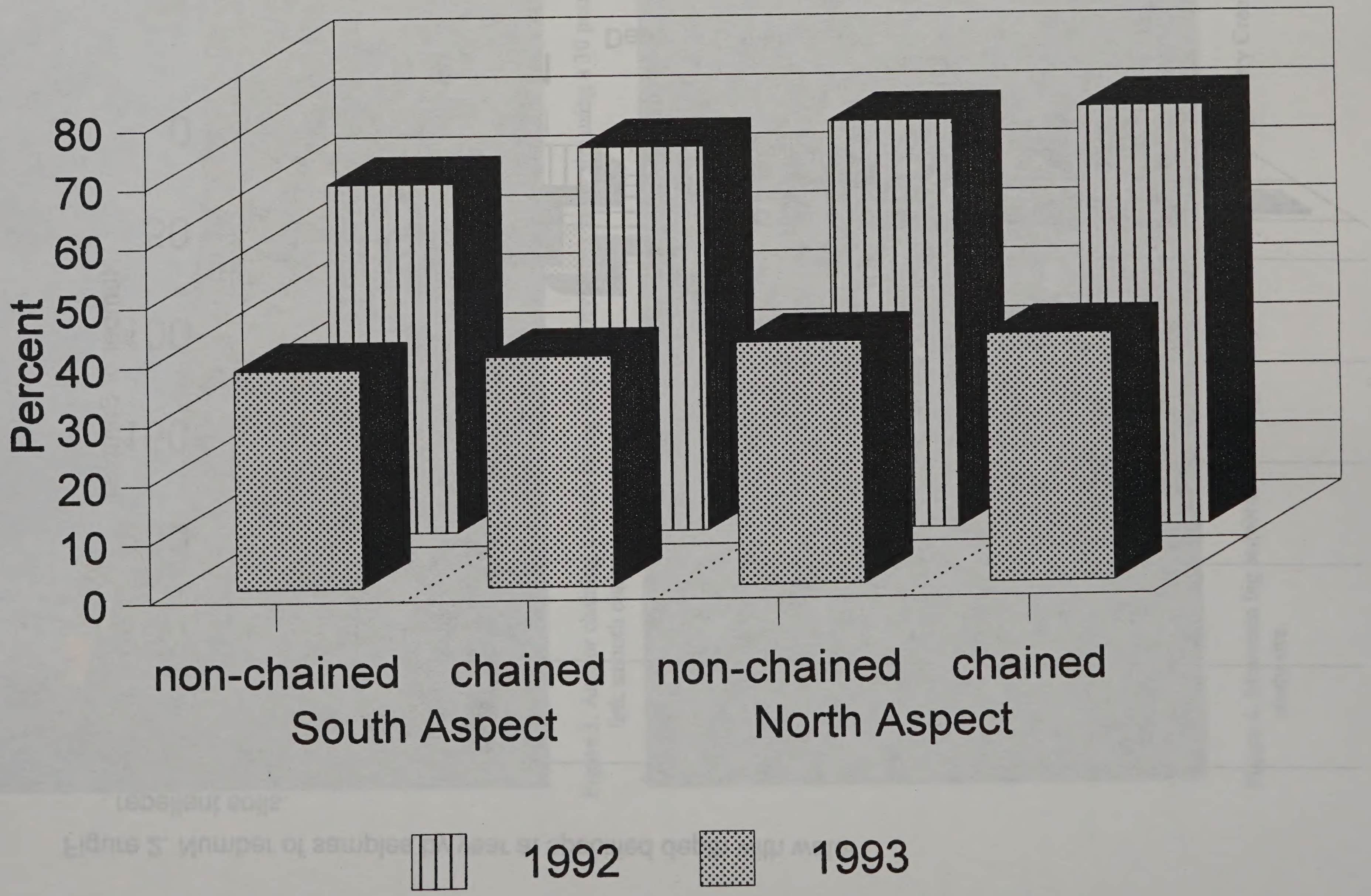
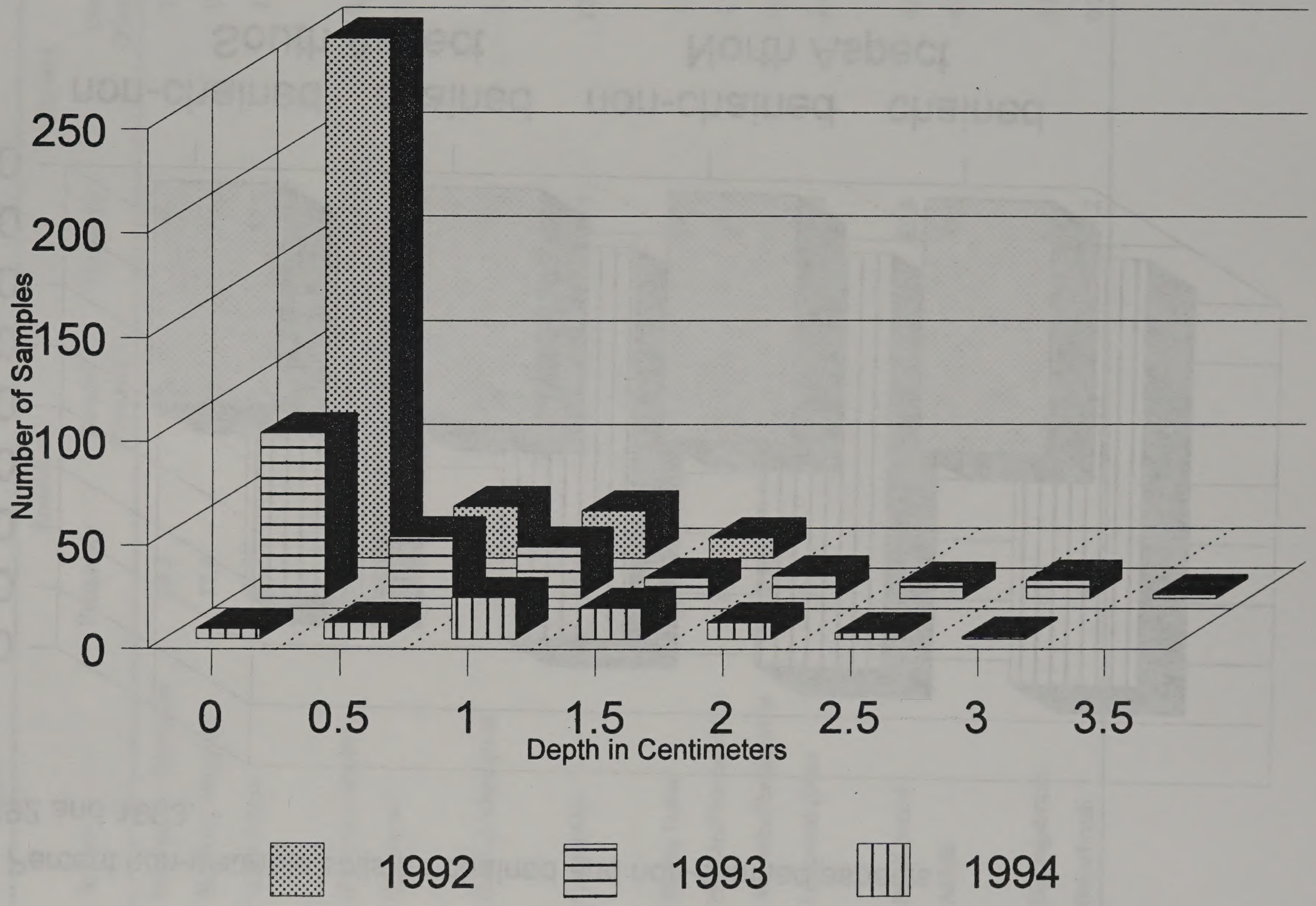


Figure 2. Number of samples by year at specified depth with water repellent soils.



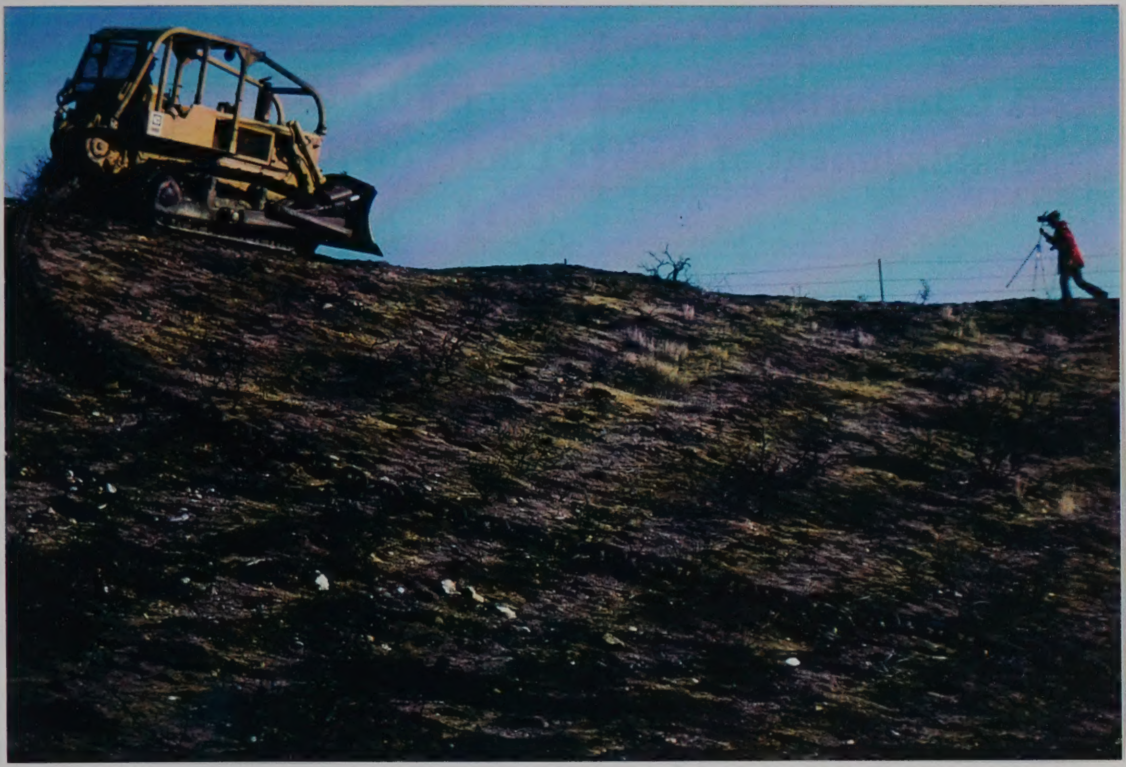


Figure 3. Anchor chaining a south facing slope at Dry Creek study site using a 30 pound link smooth chain.

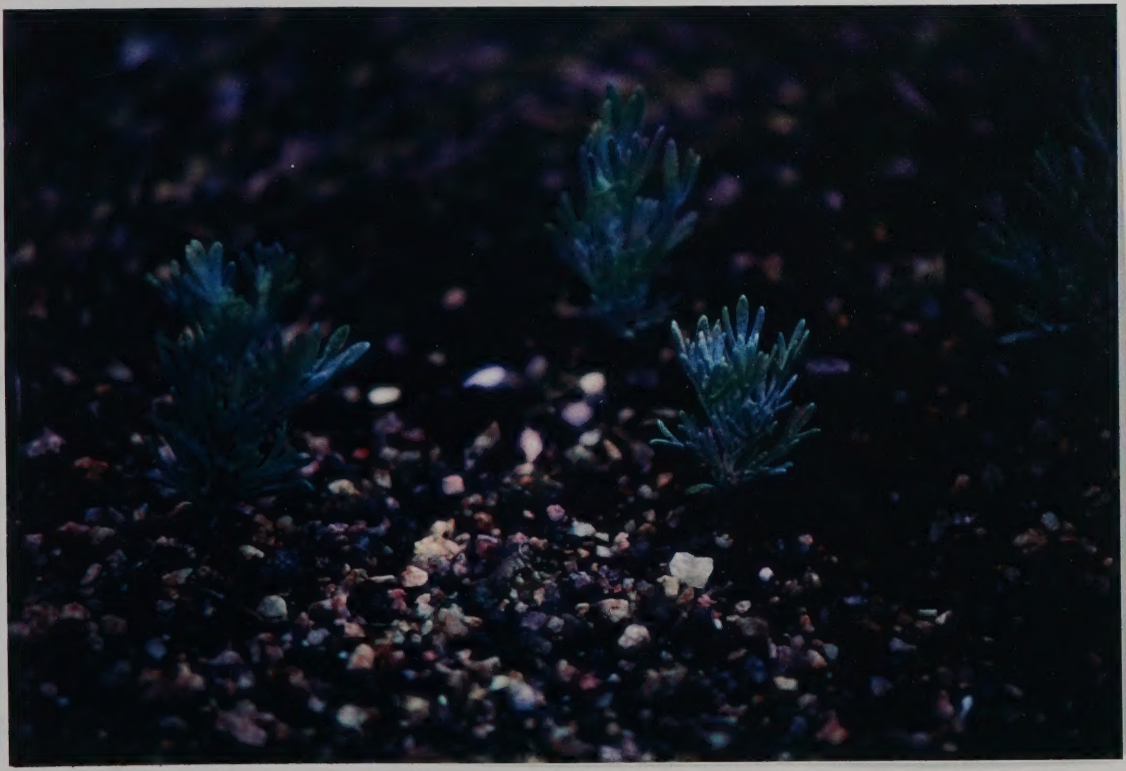


Figure 4. Mountain big sagebrush seedlings one year after aerial seeding at Dry Creek study site.

A Comparison of Site Preparation Practices and Re-establishment of Native Plants on the Boise 8th Street Fire

Stephen B. Monsen and Kelly L. Memmott

Problem

Site preparation and seeding following a fire are often complex and multifaceted decisions. Fires often create problems with soil erosion, invasion of noxious weeds and destruction of native plant communities. Various site preparation and seeding practices including drilling, aerial seeding, chaining, ripping, and the use of a pipe harrow are used to restore disturbances. Improper use of site preparation equipment and seeding inappropriate species can disrupt the recovery of existing native species. Poorly designed practices can also result in poor seedbed conditions and can create unnecessary soil disturbances. Failure to seed fire related disturbances can allow weeds to invade and subject sites to extensive erosion. Attempting to create seedbeds to plant select species without destruction of existing plants is a challenge in restoring native communities.

Introduction

Different site preparations and erosion control practices were utilized to aid in reduction of soil erosion and facilitate plant restoration of the foothills impacted by the 8th Street Fire. Some practices include construction of trenches, water bars, ripping of soil, and building check dams. Alternative treatments include chaining, and the use of a pipe harrow. The effectiveness of these and other treatments have not yet been fully determined. Ripping and trenching treatments are quite severe and have considerable impact on upon the recovery of existing native plants. Contributing factors are uprooting and soil moisture loss and abnormal freezing due the nature of the treatment. Treatments that adversely effect the recovery of the native species open the door to invasion of weeds. Cheatgrass, medusahead, and Rush skeletonweed are present within the burn and flourish with disturbance. Site preparation treatments that expose the seedbed and impede the growth of the naive plants allow the rapid expansion of these aggressive weeds. In order to allow a native plant communities to reestablish the most appropriate preparation technique should be used. Creation of seedbeds should not destroy existing plants or disrupt soil conditions. Without adequate ground cover, soil erosion and abnormal runoff will occur in subsequent years.

This study was designed to investigate the different site preparation treatments (chaining, ripping, pipe harrow, and control or no treatment) upon soil stability and recovery of native and seeded plant species.

Study Objectives

The principle objectives of the study are:

1) evaluate the effects of chaining, ripping, and pipe harrowing on soil erosion.
2) determine the effects of chaining, ripping, and pipe harrowing on recovery of native species.
3) determine the effects of chaining, ripping, and pipe harrowing on seedbed of native species.
4) evaluate effects on invasion of weeds.

Methods

An area approximately five acres, located in the 8th Street Fire was selected for the study. The site is located on a north facing slope typical of those in the burn. Within the area four methods of treatment were employed (chaining, ripping, pipe harrowing, and control or no treatment). Each study plot was 250 feet long running up the slope by 100 feet wide. Treatment plots were randomly located on the slope. Prior to the treatment the area was aerial seeded using a mixture prepared for the entire burn. Sites were then treated immediately after the seeding. This work was done in late October 1996.

In summer 1997, 20 permanent plots were established in a stratified design in each treatment. Sum frequency and percent cover were recorded at each frame by plant species. Data was recorded to be later compared and tabulated following subsequent years. For this study only one year of data was available.

Results and Discussion

Although only one year of data has been collected from this study, a few pertinent findings are apparent. Creation of seedbed conditions are required to insure broadcast seeds germinate and seedlings establish. Although big sagebrush seedlings establish from shallow planting depths, greater number of seedlings occurred in chaining, followed by ripping, pipe harrowing, and control treatments. Using sum of frequency, grasses also establish better on mechanical treatments (figure 2). Bluebunch wheatgrass and Sandberg bluegrass were favored by pipe harrowing followed by chaining and ripping. Recovery of broadleaf forbs generally favored the use of mechanical treatments (figure 3). Lewis flax and small burnet, a large seeded species, establish only on mechanical treated plots. These species require soil coverage to establish. Broadcasting seeds of these species on bare soils without some means of coverage is obviously not advised. Small seeds of alfalfa establish across all treatments , and apparently benefit by snow cover which assured establishment by maintaining moist surface conditions and protecting small seedlings from early spring frosts.

Natural recruitment of antelope bitterbrush was nearly absent from all treatments. Only one seedling was encountered among all plots. Seeding this important shrub is vital to reestablish where large and extensive fires occur.

Regrowth and recovery of most native herbs was not impaired by chaining or pipe harrowing. Ripping did disrupt and uproot a number of plants, but their recovery and survival can not, yet, be determined. The weedy invader, cheatgrass (Bromus tectorum) was equally distributed across all treatments, but its persistence amid developing competition can not be determined.

Management Implications

The significance of these findings confirm the importance of creating favorable seedbeds when areas are seeded following burning. Areas subject to burning that lack suitable plants to recover and require seeding must be properly treated to create appropriate seeded. Chaining and pipe harrowing are inexpensive and effective treatments to be used on steep slopes where minimal tillage is required. These mechanical treatments are certainly less disruptive to the recovery of herbs. Chaining can be easily regulated to achieve and create more surface disturbance than ripping. Many seeding and erosion control practices employed on this burn were inappropriate treatments.

Relevant Literature

Ratzlaff, T. A. and J. E. Anderson. 1995. Vegetal recovery following wildfire in seeded and unseeded sagebrush steppe. J. Range Manage. 48:386-391.

Figure 1. Recovery of sagebrush among mechanical treatments (sum frequency).

	Number of treatments	average or mean per treatment
Chain	3	50
Rip	1	31
Pipe Harrow	3	19
Control	2	16

Figure 2. Recovery of grasses among mechanical Treatments (sum frequency)

Species	Chain	Rip	Pipe Harrow	Control
Agsp *	36	33	64	18
Dagl *	41	22	42	31
Brte	26	24	40	26
Poa	50	13	77	9
Sihy	0	0	4	0
Trsp	5	0	2	1
* Indicates seeded species				

Figure 3. Recovery of broadleaf forbs among mechanical treatments (mean sum frequency)

Plant	Chain	Rip	Pipe Harrow	Control
Acmi *	50	30	62	66
Apan	37	32	56	54
Basa	8	2	14	4
Drve	38	41	57	17
Lase	18	11	18	6
Lile *	10	8	27	1
Luse	38	20	30	21
Mesa *	69	67	36	66
Mope	51	33	40	49
Mymi	33	25	38	9
Podo	54	51	61	37
Sami *	43	35	41	15
* indicates seeded species				

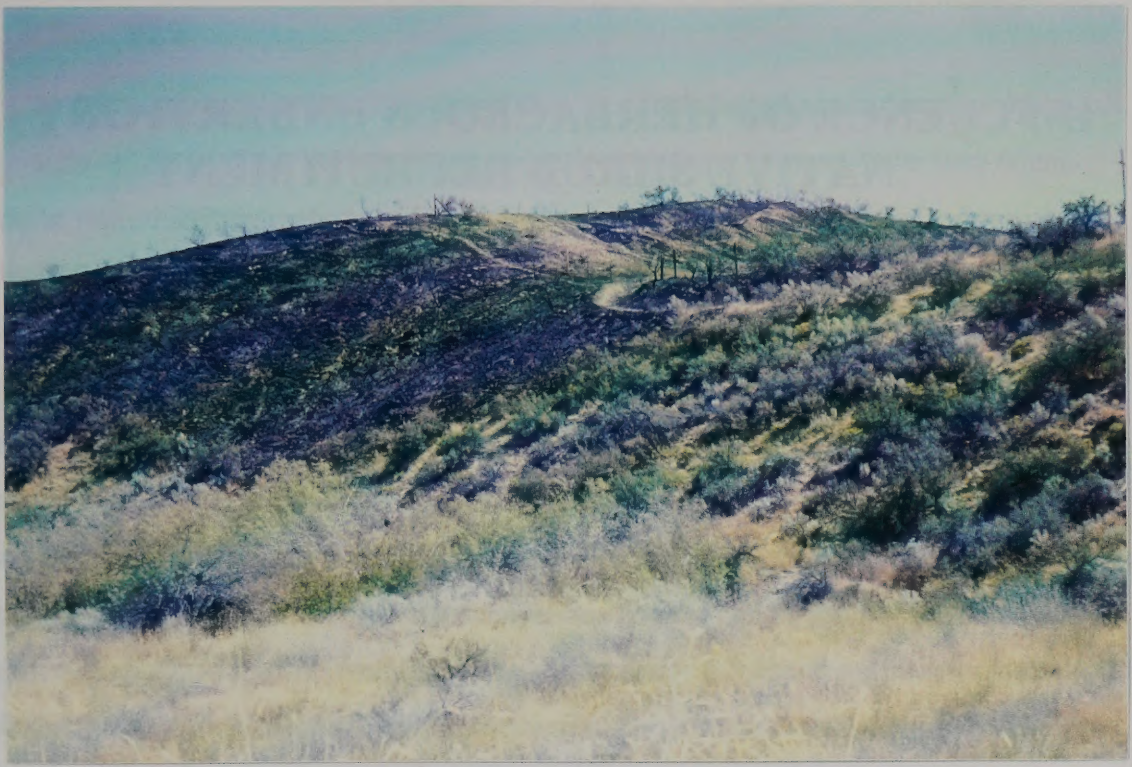


Photo 1. Burn photograph showing the loss of important browse plants

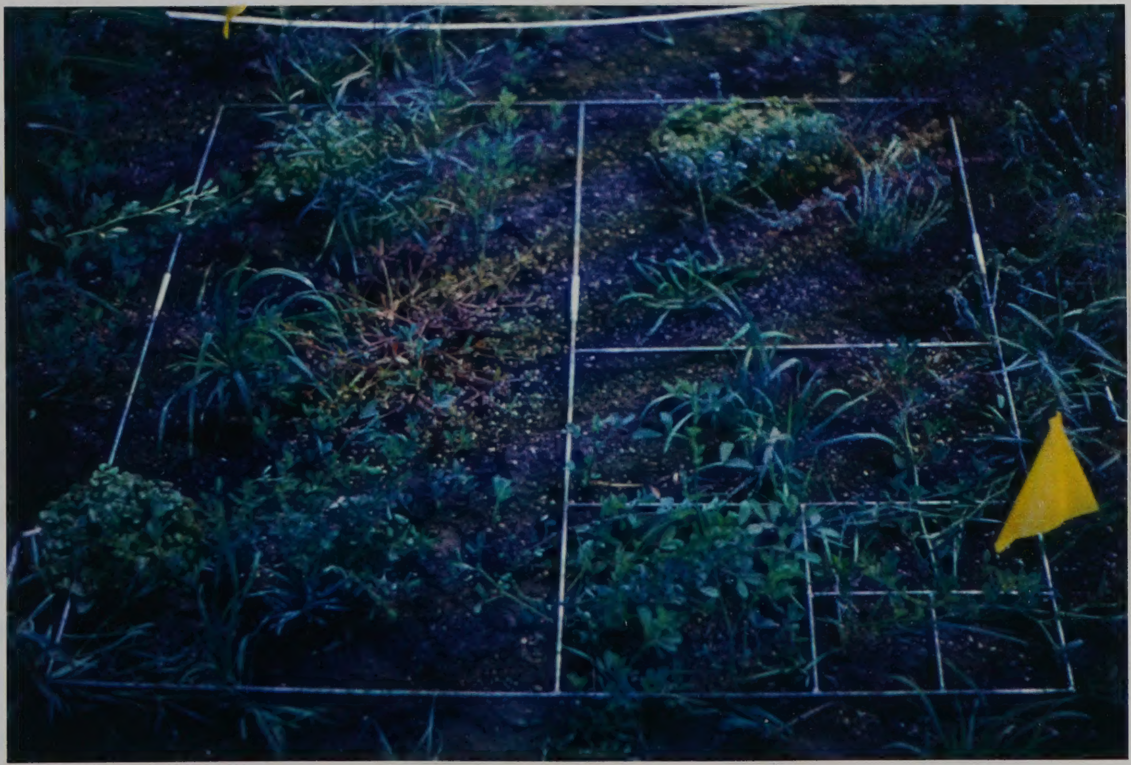


Photo 2. One meter frame used to evaluate the effectiveness of mechanical treatments.

INFLUENCE OF HERBACEOUS UNDERSTORY ON NATIVE SHRUB RECRUITMENT

Derek B. Hall, Stephen B. Monsen, and Val Jo Anderson

Problem: Native shrub stands in the Great Basin Region provide forage and habitat for several animals including domestic and wildlife species. Many of the areas where these shrub stands occur have had an influx of exotic annual and perennial plant species over the last several decades. This has created some concern that these shrub stands are becoming decadent with little or no shrub recruitment occurring. Several studies in the Sagebrush association of the Great Basin Region have reported that competition from introduced grasses negatively affects shrub recruitment (Holmgren, 1956; Hormay, 1943; Hubbard, 1959; Monsen and Shaw, 1982; Price and Brotherson, 1987). However, there is little information available on shrub recruitment in native shrub stands and the effect of understory composition. This study investigated how various life form groups of understory species affect shrub recruitment in native stands of antelope bitterbrush (Purshia tridentata Pursh.) and Stansbury cliffrose (Cowania mexicana stansburiana Torr.). It was hypothesized that natural shrub recruitment is lower in areas where introduced annual grasses dominate the understory and higher in populations where native perennial bunchgrasses are dominant.

Methods: Twenty-two sites from northern to central Utah were sampled during the late summer and early fall of 1992 and 1993 (Table 1). Of those sites, nine supported antelope bitterbrush and thirteen supported Stansbury cliffrose. Only sites that provided at least 14 percent understory basal cover and were relatively uniform in slope and aspect were included in the study.

Five 1m X 50m belt transects were distributed uniformly through each shrub stand. Shrub density and age-classes were evaluated within each transect. Age-classes were determined by the following criteria: Seedling--fewer than four main branches and less than 15cm tall; Juvenile--15cm to 60cm tall but not reproductively mature; Mature--taller than 60cm and/or reproductively mature; and Decadent--greater than fifty percent of canopy cover dead. Relative shrub recruitment rates were determined for each site by summing all seedlings and juveniles and dividing that value by the total number of shrubs in all age-classes and then multiplying by 100 (Table 2). This value represented the percentage of a shrub stand that was composed of seedlings and juveniles. Understory basal cover composition was characterized using a .25m^2, eight-point sampling frame placed at ten random locations along each transect. Understory species were divided into the following groups; PBL--perennial broadleaf herbs, PBG--perennial bunchgrasses, AG--annual grasses, and ABL--annual broadleaf herbs. Total understory basal cover was determined by summing absolute cover of all understory groups. Relative basal cover for each of the four groups was then calculated by dividing the absolute cover for each group by total cover and multiplying by 100. A principal components analysis was used to evaluate the similarity of cliffrose and bitterbrush sites considered in this study. Additionally, the relative cover of each life form group as well as total cover were used in multiple regression analyses. Absolute cover of bare ground, rock, and litter were also recorded at each study site and related to shrub recruitment using simple linear regression.

Elevation at each study site was taken from 7.5 minute USGS quadrangle maps, and precipitation data at each site was taken from an isohyetal map of Utah based on annual precipitation averaged over the thirty year period, 1930-1960 (Table 1). These environmental data were also correlated with shrub recruitment using simple linear regression. It should be noted that most of the annual grasses were introduced species, particularly cheatgrass (Bromus tectorum Linn.). Essentially all of the perennial bunchgrasses were native, with bluebunch wheatgrass (Agropyron spicatum Pursh.) being the dominant species. All percentage data were arcsin transformed in an attempt to normalize the data set.

Results and Discussion: Nine variables (precipitation, elevation, and absolute cover of bare ground, rock, litter, perennial broadleaf herbs (PBL), perennial bunchgrasses (PBG), annual grasses (AG), and annual broadleaf herbs (ABL)) were utilized in a principal components analysis. Cliffrose sites had 62% vegetative composition of annual grasses while bitterbrush sites had only 16% ($p<.01$). The same trend held true for annual broadleaf herbs with cliffrose having 16% composition and bitterbrush having 1% ($p<.01$). Price and Brotherson (1987) reported similar site preferences for Cliffrose. Conversely, bitterbrush sites had 64% composition of perennial bunchgrasses and cliffrose had 16% ($p<.01$) (Table 2). Because of the differential site preferences, recruitment for these two species was analyzed separately. Regression analysis for relative recruitment of cliffrose and bitterbrush indicated that recruitment was not significantly correlated ($p>0.1$) with any of the understory composition groupings. Recruitment for both shrub species was negatively correlated with surface rock. A comparison of the signs for r-values for recruitment of these two species suggests that bitterbrush and cliffrose probably respond differently to understory and environmental variables.

Management Implications: Bitterbrush and cliffrose occupy different kinds of sites and the various life form groups in their respective understories may affect shrub recruitment of these two species quite differently. The data resulting from this study do not support the original hypothesis and suggest that some other factor or combination of factors influence shrub recruitment success to a greater extent than does understory composition. The uneven distribution of size/aged individuals in these shrub populations suggest episodical recruitment. Natural shrub recruitment may be a stochastic event that only occurs when several environmental factors (both biotic and abiotic) combine to allow shrubs to produce abundant seed and subsequent environmental conditions are favorable for germination and survival of seedlings. When this recruitment is triggered, understory vegetative composition may still affect recruitment success. In order to ensure the long-term viability of native shrub stands in the Great Basin Region, further monitoring should be conducted periodically to check the status of recruitment into these shrub populations. In addition, future studies should focus on monitoring shrub seedlings that are recruiting into these native shrub stands to learn more about the effects of understory composition and other variables on their subsequent survival or death.

Related Publications

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Table 1. Site descriptions and data collection year for twenty-two native shrub sites in Utah.

Site Number Location	Year	Shrub spp.	Elevation (meters)	Precipitation (mm)	Dominant Grass spp.
1-Maple Canyon	92	Cliffrose	1691	503	Cheatgrass
5-Payson Canyon South	92	Cliffrose	1661	503	Cheatgrass
6-Santaquin North	92	Cliffrose	1631	503	Cheatgrass
7-Santaquin South	92	Cliffrose	1661	503	Cheatgrass
11-Fillmore	92	Cliffrose	1631	375	Cjeatgrass
12-Spring Lake	92	Cliffrose	1570	453	Cheatgrass
13-Edgemont South	93	Cliffrose	1600	523	Cheatgrass
14-Edgemont North	93	Cliffrose	1540	503	Cheatgrass
15-Payson Canyon North	93	Cliffrose	1570	503	Cheatgrass
16-Payson Canyon Middle	93	Cliffrose	1570	503	Cheatgrass
17-Mona North	93	Cliffrose	1661	503	Cheatgrass
18-Mona Middle	93	Cliffrose	1691	503	Cheatgrass
19-Mona South	93	Cliffrose	1721	503	Cheatgrass
2-Logan Canyon	92	Bitterbrush	1661	630	Cheatgrass
3-Tremonton #1	92	Bitterbrush	1661	403	Bluebunch
4-Tremonton #2	92	Bitterbrush	1661	403	Bluebunch
8-Lake Mountain	92	Bitterbrush	2250	503	Cheatgrass
9-Mt. Pleasant North	92	Bitterbrush	1842	355	Bluebunch

10-Mt. Pleasant South	92	Bitterbrush	1842	355	Bluebunch
20-Scipio	93	Bitterbrush	1873	473	Bluebunch
21-Deer Creek Reservoir	93	Bitterbrush	1721	473	Bluebunch
22-Heber	93	Bitterbrush	1721	403	Bluebunch

Table 2. Shrub recruitment and relative basal cover for perennial broadleaf herbs (PBL), perennial bunchgrasses (PBG), annual grasses (AG), annual broadleaf herbs (ABL) and absolute basal cover for plants, bare ground, rock, and litter for 22 native shrub sites in Utah.

Site Number Shrub spp.	Shrub Recruitment	PBL (%)	PBG (%)	AG (%)	ABL (%)	Total Plant Cover (%)	Bare (%)	Rock (%)	Litter (%)
1-Come	3.3	10.3	12.9	59.6	17.2	75.5	0.8	13.8	10.0
5-Come	7.0	0.6	37.0	55.3	7.2	45.3	2.5	10.3	42.0
6-Come	8.6	3.6	32.0	50.3	14.2	42.3	8.0	18.0	31.8
7-Come	9.7	45.2	10.3	34.8	9.7	38.8	14.0	19.0	28.3
11-Come	18.7	2.9	6.7	61.9	28.6	52.5	4.8	5.5	37.3
12-Come	8.3	1.5	14.6	77.7	6.3	51.5	7.3	11.0	30.3
13-Come	11.0	1.0	0.0	80.9	18.1	51.0	2.8	9.0	37.3
14-Come	7.4	0.9	22.5	62.4	14.2	54.5	7.3	13.0	25.3
15-Come	11.1	1.5	6.0	70.2	22.4	33.5	7.0	25.5	34.0
16-Come	2.6	1.5	7.4	71.9	19.2	50.8	2.0	20.3	27.0
17-Come	27.4	8.3	9.6	71.6	10.6	54.5	3.5	10.8	31.3
18-Come	6.5	5.1	18.6	50.9	25.4	44.3	6.8	19.0	30.0
19-Come	5.0	0.0	29.9	49.7	20.4	39.3	7.0	19.3	34.5
2-Putr	14.6	27.9	17.9	42.1	12.1	70.0	4.0	5.8	20.3

3-Putr	11.9	4.8	86.2	6.4	2.7	47.3	6.3	9.0	37.5
4-Putr	9.4	4.0	76.7	11.4	8.0	44.0	6.3	9.5	40.3
8-Putr	8.4	31.0	25.9	41.4	1.7	14.5	6.0	9.5	70.0
9-Putr	4.1	24.0	57.9	17.8	0.4	60.5	9.0	3.0	27.5
10-Putr	21.4	20.8	78.6	0.0	0.6	43.3	19.8	6.5	30.5
20-Putr	31.3	10.4	88.0	0.0	1.6	31.3	10.5	25.5	32.8
21-Putr	9.1	26.5	35.5	16.9	21.2	47.3	0.5	0.0	52.3
22-Putr	6.1	5.0	83.2	9.2	2.5	29.8	10.8	13.0	46.5

COMPETITIVE EFFECTS OF BLUEBUNCH WHEATGRASS, CRESTED WHEATGRASS, AND CHEATGRASS ON ANTELOPE BITTERBRUSH SEEDLING EMERGENCE AND SURVIVAL

Derek B. Hall, Val Jo Anderson, and Stephen B. Monsen

Problem: Shrubs dominate many plant communities throughout the western United States, particularly in the Great Basin. McGinnies (1972) suggested that the northern desert shrub type is among the most important shrub communities in North America. Shantz and Zon (1924) recognized three main associations in the sagebrush or northern desert shrub types, among which, is the big sagebrush (Artemisia tridentata Nutt). association. This association includes communities dominated by big sagebrush, rubber rabbitbrush (Chrysothamnus nauseosus Britt.), and antelope bitterbrush (Purshia tridentata Pursh.), among others.

These communities, consisting of a variety of small to large shrubs that form an open canopy, support a grass/forb understory. Shrub-dominated communities provide crucial winter and spring habitat for wild ungulates, particularly mule deer and elk, as well as cattle and sheep (Plummer 1972, McKell and Goodin 1973). High energy content of dry grass culms coupled with high protein levels found in the current year twig growth of shrubs provide excellent winter and spring forage (Cook 1972).

Relatively constant and heavy use by wild and domestic ungulates, as well as fire suppression, have created changes in species composition of both woody and herbaceous components of many communities. Cheatgrass (Bromus tectorum Linn.) and other annual weeds have invaded and dominate many areas within brush communities where native plant species have been weakened (Vallentine 1989). Crested wheatgrass (Agropyron cristatum Linn.) has been seeded onto millions of acres of rangeland throughout the western United States to stabilize herbage production, protect watersheds, and control weeds (Holechek 1981). Crested wheatgrass persists under heavy grazing pressure relative to many native counterparts and has been seeded into weakened native plant communities.

These introduced annual and perennial grass species appear to affect native shrub recruitment and subsequent community composition. Several studies have shown that competition from introduced grasses restricts shrub seedling emergence and/or establishment. Hormay (1943) reported that cheatgrass retarded natural establishment of antelope bitterbrush. Holmgren (1956) concluded that few bitterbrush seedlings were able to survive the first summer in cheatgrass stands. Monsen and Shaw (1983) suggested that established stands of desert wheatgrass (Agropyron desertorum Linn.), a close relative of crested wheatgrass, limited the natural regeneration of antelope bitterbrush. Price and Brotherson (1987) partially attributed low recruitment rates in stands of Stansbury cliffrose (Cowania mexicana stansburiana Torr.) to competition from annual grasses. Eissenstat and Caldwell (1988) reported that sagebrush indicator plants had lower survival, growth, reproduction, and late-season water potential in areas dominated by desert wheatgrass in contrast to areas dominated by bluebunch wheatgrass ([Pseudoroegneria spicata (Pursh.) Love]).

Native grass understories may also negatively impact shrub seedling survival (Hubbard 1959, Eissenstat and Caldwell 1988). However, research has shown that introduced annual and perennial grasses; namely, desert wheatgrass, crested wheatgrass, and cheatgrass utilize soil moisture earlier in the growing season than the native bluebunch wheatgrass because of their rooting characteristics (Harris 1967, Harris and Wilson 1970, Harris 1977, Caldwell and Richards 1986, Aguirre and Johnson 1991). The ability of these introduced grasses to utilize soil moisture earlier in the growing season than bluebunch wheatgrass gives these species a competitive advantage over bluebunch wheatgrass and quite possibly, over other native species as well. Although bluebunch wheatgrass competes with shrub seedlings, it may not have as detrimental an effect on shrub seedling survival as the previously discussed introduced species (Eissenstat and

Caldwell 1988).

This study was designed to determine the effect of various understory species; namely, cheatgrass, Hycrest crested wheatgrass, and Goldar bluebunch wheatgrass on 1) soil moisture depletion in the top 114 cm of the soil profile, 2) the xylem pressure potential of antelope bitterbrush seedlings, and 3) the emergence and subsequent survival of antelope bitterbrush seedlings. The hypothesis tested was that shrub seedling emergence and subsequent survival is lower in areas dominated by the introduced grass species (cheatgrass and crested wheatgrass) than in areas dominated by bluebunch wheatgrass, because of the introduced species' ability to exploit soil moisture better and/or earlier than bluebunch wheatgrass.

Methods: The study area is located four and a half kilometers south of Nephi, Utah at an elevation of 1385 m. Soil at the site is classified as a Nephi silt loam. This soil is a fine-silty, mixed, mesic Calcic Argixeroll with a soil pH of approximately 8.3. Average annual precipitation is 356-406mm, mean annual air temperature is 7-11 degrees C., and the average freeze-free season is 100 to 140 days.

Twenty-four competitive matrix plots, consisting of eight replicate plots of each of the three grass species (Goldar bluebunch wheatgrass, Hycrest crested wheatgrass, and cheatgrass), and four control plots were established in the fall of 1991 and 1992. The two wheatgrass species were greenhouse propagated and transplanted to the study site in the fall of 1991. At the time of transplanting, plants were approximately 6 months old. Goldar bluebunch wheatgrass is a cultivar native to the Palouse prairie. Hycrest is a cultivar of crested wheatgrass and is commonly seeded on western rangelands. Transplants were placed at .5m spacings in 9m^2 matrices with 49 plants in each matrix. Young plants were watered periodically through the first two growing seasons to ensure establishment of these young grasses and development of a uniform and strong competitive matrix. Cheatgrass seed was collected near the study site and seeded in rows spaced 20 cm apart in the fall of 1992.

During the summer of 1992 a rodent-proof fence was erected around the site to keep unwanted rodents from eating the shrub seeds. The site was also weeded several times during the summer in an attempt to reduce the confounding effects of weeds in the experiment.

In the fall of 1992, approximately 25 antelope bitterbrush seeds were sown into each of four interspaces in the interior of each competitive matrix and each control plot. In addition, aluminum tubes were implanted to a depth of about 114 cm in half of the plots to provide access for a neutron probe for soil moisture monitoring.

Soil moisture, xylem pressure potential of bitterbrush seedlings, and bitterbrush seedling densities were measured and recorded at seven dates through the spring and summer of 1993; 1) April 29, 2) May 13, 3) May 20, 4) May 27, 5) June 4, 6) June 25, and 7) August 2. In addition, bitterbrush seedling densities were recorded again in July of 1994 to determine percent survival. Soil moisture was measured with a neutron probe in the lower profile (22 cm-114 cm), and gravimetrically in the top 22 cm. Soil moisture was reported as percent by volume.

Pre-dawn xylem pressure potentials were measured with a Scholander type pressure bomb (Waring and Cleary 1967). At each sampling date, one shrub seedling was sacrificed and measured from each plot to determine xylem pressure potential, except when bitterbrush seedling density per plot fell below five plants. Additionally, seedlings were counted in each interspace; numbers of living and dead seedlings were recorded at each sampling date.

In late May, one-half of all the grass plots were defoliated to remove 80% of the foliage to simulate heavy spring use by ungulates. A standard height/weight relationship procedure was used to determine the defoliation height for various utilization levels. Biomass was also measured by weighing the clipped material and then determining its dry weight in grams. Bur buttercup (Ranunculus testiculatus Crantz), other weedy species, and cheatgrass densities were measured along with height and basal circumference of wheatgrass species to quantify the competitive matrices.

Standard analysis-of-variance and linear regression procedures were used to analyze the data. Fisher's LSD mean separation procedure was used to determine treatment differences with a significance level of alpha=0.05.

Results and Discussion: When data was collected in the spring of 1993, the average bunchgrass was approximately 50 cm in circumference and cheatgrass densities averaged 914 plants per square meter in the cheatgrass plots. Biomass in the grass plots was regressed against percent survival at the date of defoliation (May 20). There was no significant relationship between these two variables.

Although the site was weeded several times the previous summer, bur buttercup seed persisted in the soil and germinated the following spring. Bur buttercup densities among competitive matrices differed significantly from one another (Figure 1 ($p<0.01$). Bur buttercup densities averaged 47 (a), 76 (b), 92 (bc) and 106 (c) plants/m^2 in crested wheatgrass, bluebunch wheatgrass, control, and cheatgrass plots, respectively (Letters following values show significant differences (alpha=0.05) among matrices. Values not containing similar letters are significantly different from each other). The high bur buttercup densities in the cheatgrass plots, combined with the cheatgrass, formed an annual competitive matrix rather than a simple cheatgrass competitive matrix. Control plots also had high bur buttercup densities which may have influenced soil moisture, bitterbrush seedling survival and bitterbrush seedling xylem pressure potentials. Bur buttercup densities were significantly higher in bluebunch wheatgrass stands than in crested wheatgrass stands, suggesting that crested wheatgrass is a stronger competitor than bluebunch wheatgrass.

Results from the soil moisture analysis showed that defoliation had no significant effect on soil moisture. The two-way interaction for soil moisture between date and depth was significant (Figure 2, $p<0.01$) This indicates that soil moisture in the upper portions of the soil profile fluctuates significantly in response to pulses of precipitation, and water loss is much faster in the upper 50 cm than in the lower part of the profile. Cline and others (1977) also determined that water loss was especially rapid in surface soil layers and less rapid deep in the soil profile. Soil moisture in the upper part of the soil profile is critical to establishing shrub seedlings which rely heavily on adequate soil moisture in the upper soil profile, especially early in the growing season and during dry years. The analysis also shows a depletion curve for moisture in the soil profile through the summer. Even the deepest part of the sampled soil profile shows a loss of soil moisture over time. The competitive matrix by soil depth interaction for soil moisture was also significant (Figure 3, $p<0.01$). Crested wheatgrass tended to draw more moisture out of the soil profile than bluebunch or cheatgrass in the top 84 cm. This is consistent with our hypothesis as well as the findings of Eissenstat and Caldwell (1988). They reported that desert wheatgrass depleted more moisture from the soil profile than did bluebunch wheatgrass. Soil moisture in the bluebunch and cheatgrass plots did not significantly differ from each other, although soil moisture was consistently slightly higher in bluebunch plots in the upper 53 cm of the soil profile. Below 53 cm soil moisture was slightly higher in cheatgrass plots than in bluebunch wheatgrass plots. This is consistent with the findings of Cline and others (1977) who concluded that soil water stored below 50 cm in a cheatgrass community was not fully exploited. Our hypothesis was not supported statistically. This discrepancy may be explained in part by the higher than normal precipitation in May and June, which may have allowed soil moisture in the cheatgrass plots to remain relatively high. This study should be repeated during a dry spring to determine if soil moisture in cheatgrass plots is significantly less than in bluebunch wheatgrass plots.

Results from the analysis of bitterbrush seedling xylem pressure potentials showed no significant effects of the defoliation treatment. This suggests that spring grazing of grasses during wet springs does not negatively affect the water status of bitterbrush seedlings.

The two-way interaction between competitive matrix and date was significant for bitterbrush xylem pressure potentials (Figure 4, p<0.01). Shrub seedlings in the bluebunch plots tended to have less negative xylem pressure potentials than seedlings in the other plots. Seedlings in crested plots exhibited the most negative pressure potentials late in the season as soil moisture declined. Eissenstat and Caldwell (1988), obtained similar results using desert wheatgrass with Wyoming big sagebrush transplants as indicator plants. They found that, "(Artemisia) indicator plants had lower survival, growth, reproduction, and late-season water potential in the neighborhoods dominated by (Agropyron desertorum), than in those dominated by (Agropyron spicatum) (bluebunch wheatgrass)."

Bluebunch wheatgrass has co-evolved with various shrubs, including antelope bitterbrush. Thus, it is reasonable to assume that these species are able to coexist. When the temporal physiological activity balance within native communities is disrupted with the introduction of cheatgrass and crested wheatgrass, the seedlings of many native shrub species may be unable to successfully compete for the limited moisture and nutrients. If shrub recruitment is inhibited, existing shrub stands will eventually become decadent and slowly disappear.

No significant differences (p=0.08) were detected among competitive matrices for bitterbrush seedling emergence. In the spring of 1993, an average of 156, 148, 134, and 93 bitterbrush seedlings emerged in each crested wheatgrass, bluebunch wheatgrass, control, and cheatgrass plot, respectively. When seedling numbers were regressed against total annuals (cheatgrass + annual forbs) per square meter, a significant negative relationship (r^2=0.99) was revealed. As the number of annuals increased, the number of bitterbrush seedlings decreased. Therefore, emergence was affected more by annual species' densities than by whether a species was introduced or not.

Results from the analysis of bitterbrush seedling survival showed no significant effects of the defoliation treatment. Significant differences (p=0.03) were detected among competitive matrices for percent bitterbrush seedling survival at the end of the first summer (Figure 5). Percent bitterbrush seedling survival averaged 19.7, 11.9, 7.1, and 6.6

in bluebunch wheatgrass, crested wheatgrass, control, and cheatgrass plots; respectively. When initial emergence is multiplied by percent survival, bitterbrush seedling densities averaged 29, 19, 10, and 6 bitterbrush seedlings per bluebunch wheatgrass, crested wheatgrass, control, and cheatgrass plot; respectively, in August 1993. No significant difference between percent seedling survival in bluebunch and crested plots was exhibited, although that trend is evident. Percent bitterbrush seedling survival was significantly higher in bluebunch plots than in the cheatgrass and control plots. The analysis also showed a trend for higher seedling survival in crested plots than in the cheatgrass and control plots. One reason for lower survival in the cheatgrass and control plots, versus the wheatgrass plots, may be the tendency for bur buttercup densities to be higher in the control and cheatgrass plots than in the wheatgrass plots, and bur buttercup has been shown to be a strong competitor which negatively affects establishing plants (Buchanan et al. 1978, Davis and Harper 1990). Although not the only factor, high densities of bur buttercup most likely affected percent survival in control and cheatgrass plots. In addition, bitterbrush seedlings did not have any substantial thermal or protective cover in the relatively open control and cheatgrass plots compared to the two wheatgrass plots. This may also have affected bitterbrush seedling survival.

Results from the July 1994, data showed an overall decline in percent bitterbrush seedling survival from the previous year for each of the competitive matrices. No significant differences (p=0.08) were detected among competitive matrices for percent bitterbrush seedling survival in July 1994 (Figure 5). Percent bitterbrush seedling survival was 12.3, 5.7, 4.5, and 4.3 in bluebunch wheatgrass, crested wheatgrass, control, and cheatgrass plots; respectively. When initial emergence is multiplied by percent survival, bitterbrush seedling densities averaged 18, 9, 6, and 4 bitterbrush seedlings per bluebunch wheatgrass, crested wheatgrass, control, and cheatgrass plot; respectively. Although not statistically significant, a strong trend for higher bitterbrush seedling survival in bluebunch plots versus all other plots is evident.

Date was also significant, with a steady decrease in percent survival over time (Figure 5, Date $p<0.01$). It should be noted that some of the shrub seedling mortality was caused by insects and destructive sampling for xylem pressure potential measurements.

Management Implications: The four competitive matrices affected soil moisture, bitterbrush seedling xylem pressure potentials, and bitterbrush seedling emergence and subsequent survival differently. Bur buttercup emerged in high densities in the control and cheatgrass plots and in lesser densities in the bunchgrass plots. Crested wheatgrass plots had significantly lower bur buttercup densities than did bluebunch wheatgrass plots, suggesting crested is a better competitor than bluebunch against bur buttercup. Bur buttercup affected soil moisture, bitterbrush seedling xylem pressure potentials, and bitterbrush seedling emergence and survival.

Soil moisture tended to be higher in bluebunch wheatgrass plots than in crested wheatgrass plots in the top 84 cm of the soil profile, which shows that crested depletes soil moisture more than bluebunch does. Although not significant, soil moisture in the upper 53 cm was consistently slightly higher in bluebunch wheatgrass plots than in cheatgrass plots. Perhaps these differences would have been significant if this study was conducted in a year with below-normal precipitation.

Bitterbrush seedling emergence was significantly negatively correlated with annual species' density which proves that annual forbs and cheatgrass negatively affect bitterbrush seedling emergence. In addition, a strong trend indicating percent survival of bitterbrush seedlings to be higher and bitterbrush xylem pressure potentials to be less negative in bluebunch wheatgrass plots than in all other plots was exhibited.

Results from this study support the hypothesis that introduced species such as crested wheatgrass and cheatgrass, as well as bur buttercup, have more of a negative effect on and lower the survival of bitterbrush seedlings more than the native bluebunch wheatgrass. This negative effect can be attributed, at least in part, to the ability of these introduced species, especially crested wheatgrass, to extract more soil moisture than bluebunch wheatgrass. The fact that bitterbrush seedlings in bluebunch wheatgrass plots had less negative xylem pressure potentials than seedlings in the other plots further supports the hypothesis that crested wheatgrass, cheatgrass, and bur buttercup are able to exploit soil moisture better than the native bluebunch wheatgrass. This study did not show that the introduced species are able to exploit soil moisture earlier than bluebunch wheatgrass. Further studies should be conducted during a dry spring to determine if significant differences in soil moisture exist between cheatgrass and bluebunch wheatgrass, and to further investigate timing of soil moisture depletion in the different competitive matrices.

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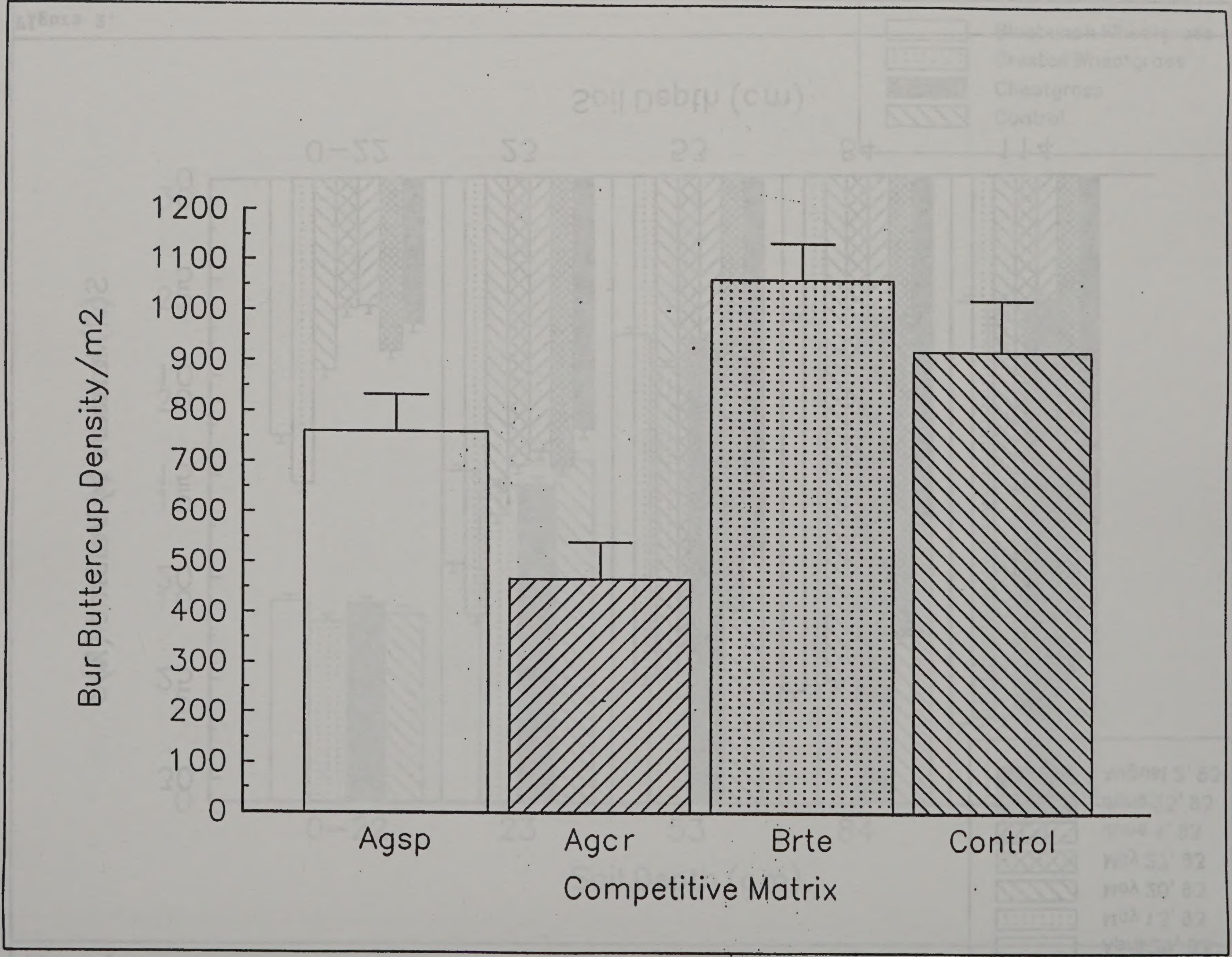
Bur Buttercup Density/m2
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Agsp
Agcr
Brte
Control
Competitive Matrix

Figure 1.

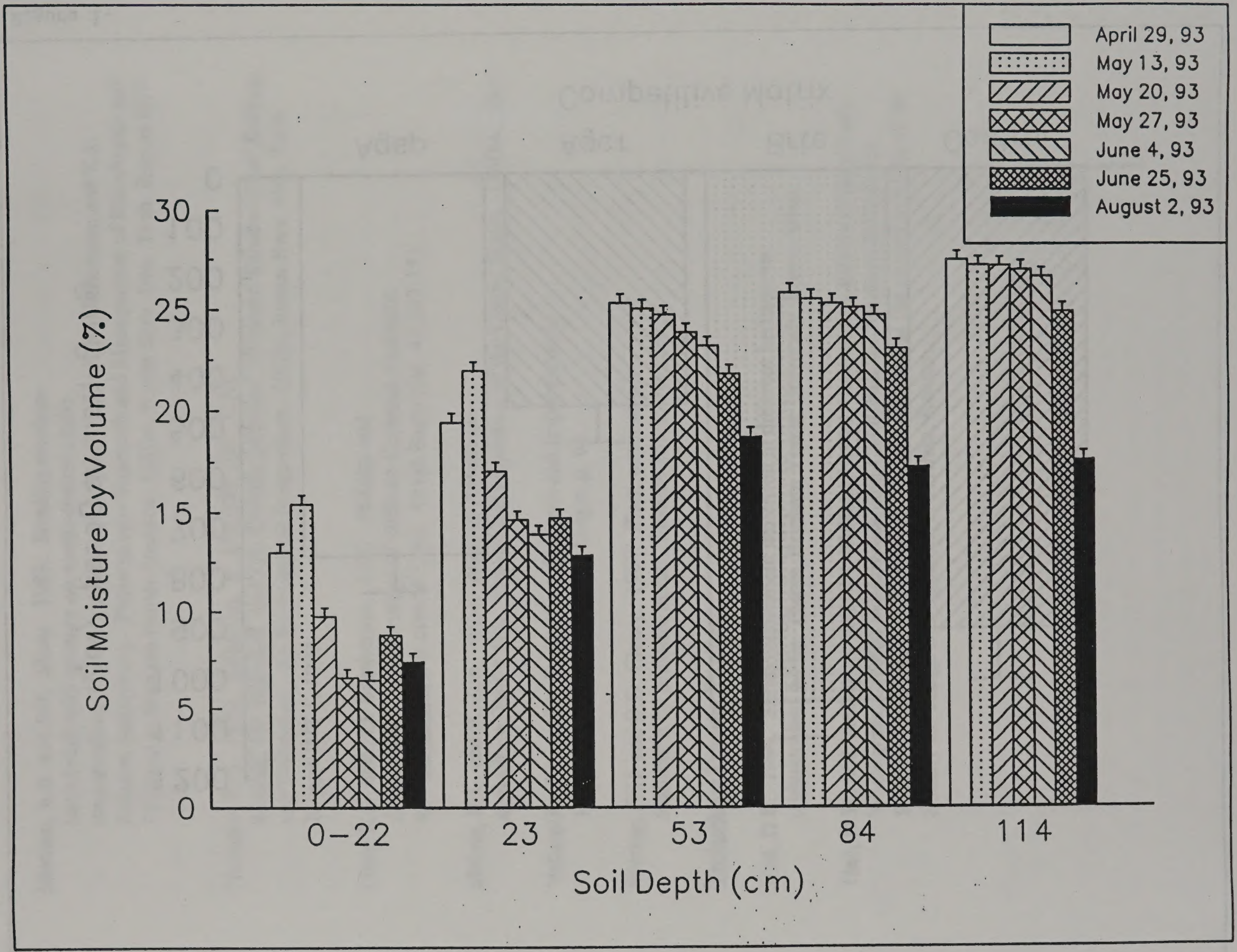
April 29, 93
May 13, 93
May 20, 93
May 27, 93
June 4, 93
June 25, 93
August 2, 93
Soil Moisture by Volume (%)
30
25
20
15
10
5
0
0–22
23
53
84
114
Soil Depth (cm)

Figure 2.

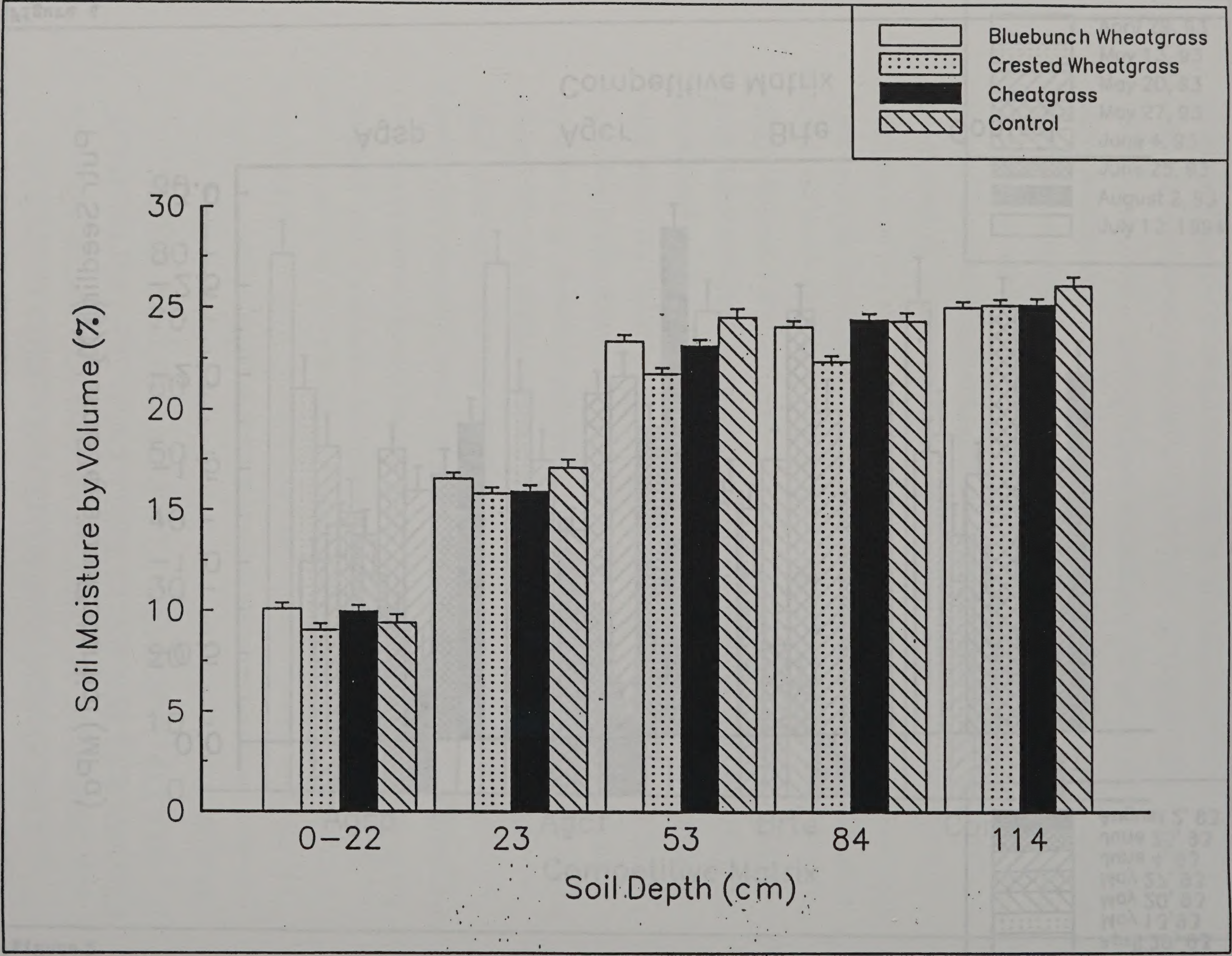
Bluebunch Wheatgrass
Crested Wheatgrass
Cheatgrass
Control
Soil Moisture by Volume (%)
30
25
20
15
10
5
0
0–22
23
53
84
114
Soil Depth (cm)

Figure 3.

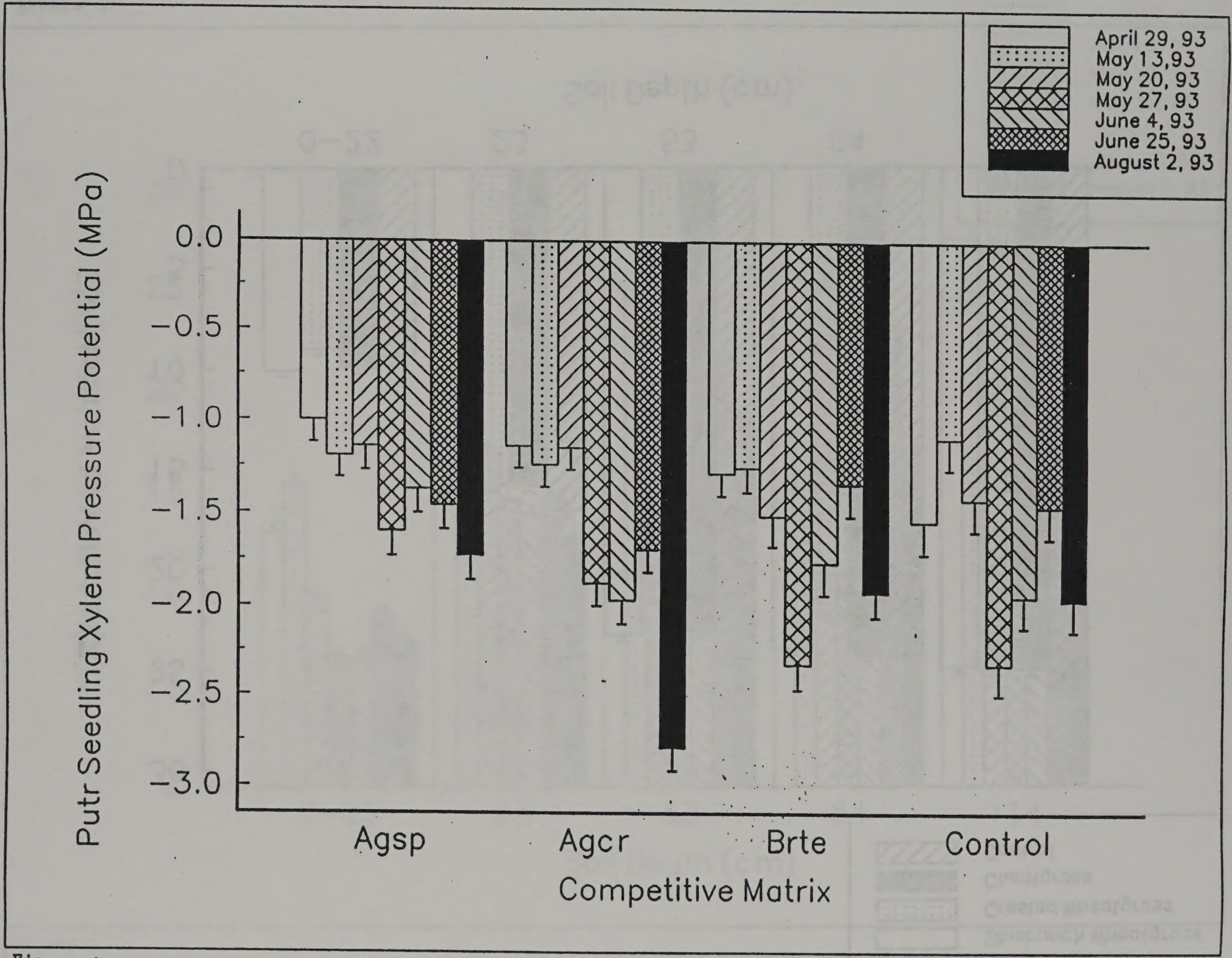
April 29, 93
May 13,93
May 20, 93
May 27, 93
June 4, 93
June 25, 93
August 2, 93
Putr Seedling Xylem Pressure Potential (MPa)
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
−3.0
Agsp
Agcr
Brte
Control
Competitive Matrix

Figure 4

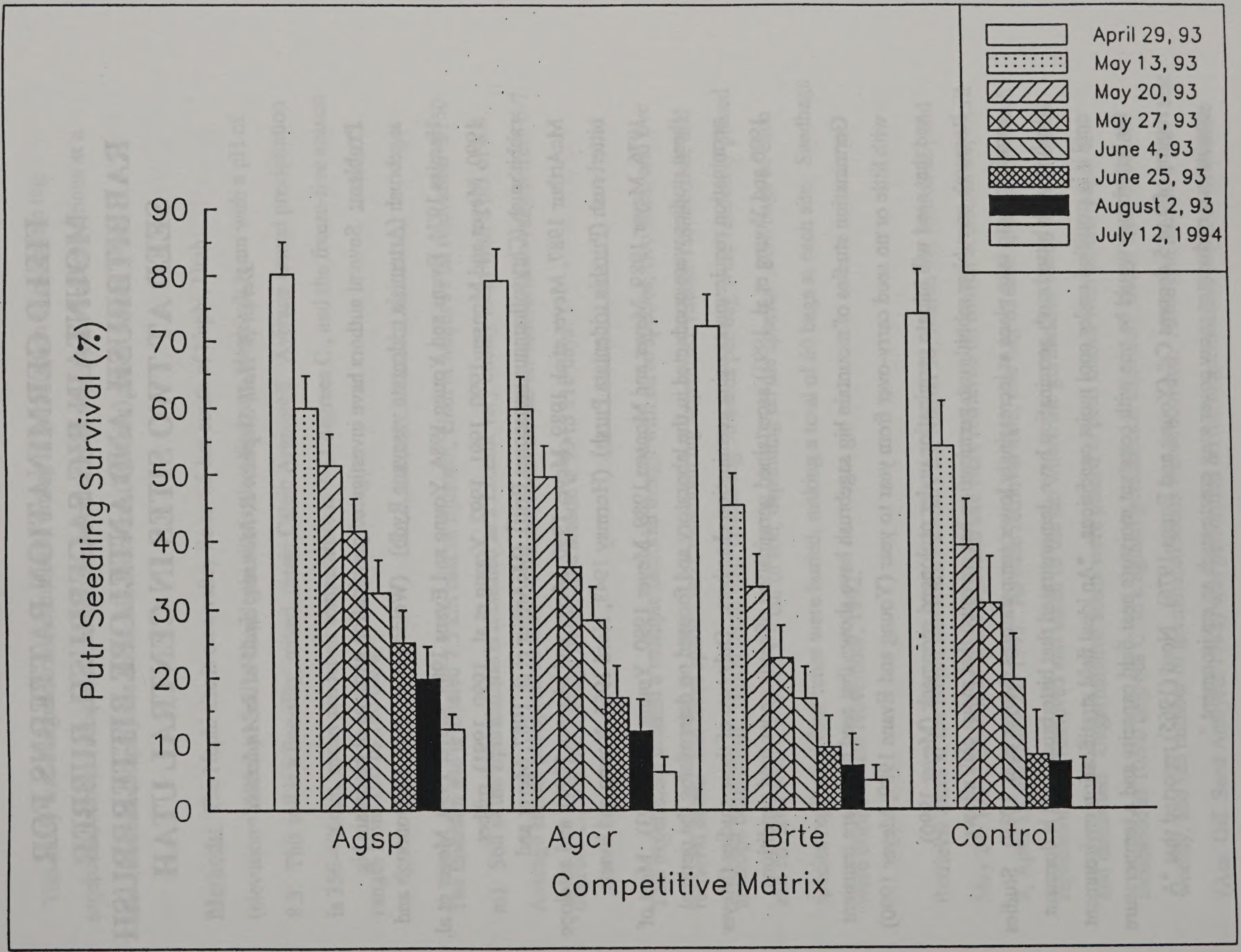
April 29, 93
May 13, 93
May 20, 93
May 27, 93
June 4, 93
June 25, 93
August 2, 93
July 12, 1994
Putr Seedling Survival (%)
0
10
20
30
40
50
60
70
80
90
Agsp
Agcr
Brte
Control
Competitive Matrix

Figure 5

FIELD GERMINATION PATTERNS FOR MOUNTAIN BIG SAGEBRUSH, RUBBER RABBITBRUSH, AND ANTELOPE BITTERBRUSH SEED AT TWO SITES IN CENTRAL UTAH

Derek B. Hall, Stephen B. Monsen, and Val Jo Anderson

Problem: Several authors have investigated germination patterns of mountain big sagebrush (Artemisia tridentata vaseyana Rydb). (Weldon et al. 1959, McDonough and Harniss 1974, Evans and Young 1984, Young and Evans 1989, Meyer 1990, Meyer et al. 1990, Meyer and Monsen 1990, 1991, 1992, Young et al., 1990, 1991), rubber rabbitbrush (Chrysothamnus nauseosus Britt). (McArthur et al. 1987, Meyer and McArthur 1987, Meyer et al. 1989, Meyer 1990, Meyer and Monsen 1990), and antelope bitterbrush (Purshia tridentata Pursh). (Hormay 1943, Nord 1965, Young and Evans 1976, Meyer 1989, Meyer and Monsen 1989, Meyer 1990, Young et al. 1993). Most of these studies were conducted in the laboratory and focused on determining the optimal germination requirements using germination chambers. Only two of these studies (Meyer 1990 and Young et al. 1993) ascertained germination of seeds under field conditions.

Germination studies of mountain big sagebrush have shown that seed banks are transient with little or no seed carry-over from year to year (Young and Evans 1989, Meyer 1990) and that seed will initiate germination under prolonged snowpack (Meyer 1990). Research on rubber rabbitbrush germination has revealed that moist chill allows germination to take place at increasingly lower temperatures (Meyer et al. 1989). Studies dealing with bitterbrush germination have demonstrated that bitterbrush seed is dormant until it is stratified under cool moist conditions. "An ideal field stratification environment for bitterbrush would be one with constant moisture near field capacity and a temperature regime of 0 to 5 degrees C." (Young and Evans 1976). Nord (1965) reported that "A continuous midwinter snow cover may create such an environment."

This study was designed to determine the timing of germination of mountain big sagebrush, rubber rabbitbrush, and antelope bitterbrush seed under field conditions at a low-elevation (Nephi) site and a mid-elevation (Ephraim) site in central Utah.

Methods: The Nephi site is on a valley floor 4.5 km south of Nephi, Utah (elevation=1385 m). Soil at the Nephi site is classified as a Nephi silt loam with a pH of 8.3. This soil is a fine-silty, mixed, mesic Calcic Argixeroll. Average annual precipitation is 356-406mm, mean annual air temperature is 7-11 degrees C., and the freeze-free season ranges from 100 to 140 days.

The Ephraim site is located 7.5 km east of Ephraim, Utah at Major's Flat (elevation=2150 m). Soil at the Ephraim site is classified as a Lizzant very cobbly loam with a pH of 8.4. Average annual precipitation is 356-508mm, mean annual air temperature ranges from 6-7 degrees C., and the average freeze-free season is 90 to 110 days.

This experiment utilized a multiple factorial design with three species, two sites, and five retrieval dates. The three species were mountain big sagebrush, rubber rabbitbrush, and antelope bitterbrush. Nylon mesh bags containing 50 seeds per bag were randomly placed and covered with 0.3 cm to 1.3 cm of soil, depending on the species. Five bags of each species replicated four times were buried, making a total of 60 bags at each site. Seedbags were buried in late November, 1992.

Retrieval dates at the Nephi site were February 25, March 11, March 18, March 25, and May 24, 1993. Seedbags at the Ephraim site were retrieved on March 2, March 25, April 8, April 15, and May 24, 1993. At each retrieval date, one bag of each species from each replication was retrieved and taken to the lab where the germinated seeds were counted and discarded. Ungerminated seeds were placed in petri dishes with blotter paper and incubated at 10/20 degrees C. in a lighted germination chamber. Seeds were checked weekly, and the number of germinated seeds were recorded. After one month, a "cut" test (Ass. Off. Seed Analysts 1988) was performed on the ungerminated seeds to determine the proportion that were still viable.

All data were arcsin transformed to normalize the percentage data. Standard analysis-of-variance procedures were then used to analyze the transformed data. Percentage values presented in tables and figures are non-transformed values.

Results and Discussion: The three-way interaction between site, species and retrieval date for laboratory germination percentages was highly significant (Figures 1a and 1b, $p<0.01$). Laboratory germination included only those seeds that did not germinate in the field, but did germinate in the germination chamber. Results from both sites showed similar laboratory germination patterns for mountain big sagebrush. About six percent of the seed did not germinate in the field but did germinate in the laboratory. Such seed may have carried over to the next fall or winter and germinated when favorable moisture and temperature conditions occurred again. These results are consistent with what Young and Evans (1989) and Meyer (1990) reported. They determined that seed banks of mountain big sagebrush are transient with little or no seed carry-over from year to year. Furthermore, mountain big sagebrush seed in natural environments has a light requirement for germination. The light requirement can be reduced by appropriate chilling (Meyer et al. 1990). The sagebrush seed in this study was buried and chilled through the winter, and most of the light requirement may have been removed. The six percent that germinated in the lab was exposed to light in the germination chamber and may have responded to the light by germinating because its light requirement had not been reduced by chilling. The rubber rabbitbrush and bitterbrush had virtually no viable seed left after the last retrieval date (May 24) at both sites (Figures 1a and 1b, $p<.01$). No dormancy was exhibited by any of the species.

Results from the mountain big sagebrush field germination data reveal that the two-way interaction between site and retrieval date was significant at $p<0.01$. In addition, a substantial amount of mountain big sagebrush seed germinated under the snow on the first retrieval date at both sites (Tables 1 and 2). Meyer (1990) reported similar results. By the second retrieval date, snow had melted from both sites. Also on the second retrieval date, big sagebrush seed reached maximum field germination at both sites. This is consistent with the findings of McDonough and Harniss (1974). They reported that, "Under natural conditions the combined effects of winter stratification on the promotion of growth of the embryo and erosion of the pericarp by weathering and by the action of soil micro-organisms probably insure prompt and nearly complete germination by the time of snowmelt in spring." Sagebrush field germination at the Ephraim site was 13% higher than at the Nephi site.

Almost half of the rubber rabbitbrush seed germinated under the snow by the first retrieval date. By the second retrieval date, after snow had melted from both sites, maximum field germination had been reached at both the Nephi and Ephraim sites (Tables 1 and 2). These results are consistent with the findings of Meyer and others (1989) who determined that if the original rubber rabbitbrush seed source is in an area with the prospect of a prolonged period of winter snowpack, the seeds should germinate toward the end of the prolonged chill period or right after spring melt-off on these sites. Meyer (1990) also reported that maximum field germination occurred within nine days after snowmelt. No significant difference between maximum field germination was evident between the Nephi and Ephraim sites.

The two-way interaction between site and retrieval date for bitterbrush field germination was significant at p=0.02. Bitterbrush seed at both Ephraim and Nephi began to germinate under the snow, but did not reach maximum field germination, until one to one and one-half months after the first retrieval date (Tables 1 and 2). Similar results were obtained by Young et. al. (1993) with optimum field germination in their retrieval study occurring between March and May. In contrast, Meyer (1990) determined that maximum field germination occurred within nine days after snowmelt. The time between the first (March 2) and second (March 25) retrievals at Ephraim, about three weeks, is the same time between the first (Feb. 25) and the third (March 18) retrieval dates at Nephi, again about three weeks. This would explain the difference in germination rates between the two sites.

Maximum germination at Ephraim was about 22% higher than at Nephi. Sagebrush showed the same trend but rabbitbrush did not differ significantly between sites. An early winter thaw may have allowed some bitterbrush and sagebrush seeds to germinate and go undetected at Nephi due to non-continuous snow cover, but rabbitbrush seed should have responded similarly. Another explanation may be that there was a soil-borne pathogen at Nephi that may have damaged some of the bitterbrush and sagebrush seed and made it non-viable, but did not have an effect on rabbitbrush seed. Young and Evans (1976) demonstrated that bitterbrush seeds with stratification requirements satisfied were very susceptible to pathogens and that the contents of the seed coat became liquefied. Many bitterbrush seeds in our study had the contents of the seed coat liquefy, and seed at both sites should have had their stratification requirements met. Again, rabbitbrush seed did not appear to be affected by whatever caused sagebrush and bitterbrush seed to become non-viable at the Nephi site.

Management Implications: Essentially all of the viable bitterbrush and rabbitbrush seed germinated under field conditions at both sites by the last retrieval date, whereas six percent of the sagebrush seed at each site did not germinate under field conditions but did germinate in the germination chamber. Therefore, a small percentage of seeded mountain big sagebrush seed could potentially carry over from one year to another, whereas no carry over of seeded rabbitbrush or bitterbrush seed would be expected.

A substantial amount of sagebrush and rabbitbrush seed germinated under snowpack and reached maximum germination by the second retrieval date, right after the snow had melted off the plots. No significant difference in maximum field germination of rabbitbrush between the two sites was detected. Conversely, 13% more sagebrush seed germinated at the Ephraim site than at the Nephi site. Bitterbrush germination percentages at Ephraim were also significantly higher than at Nephi by 22%. Possible explanations for the lower bitterbrush and sagebrush germination percentages at Nephi include 1) an early winter thaw at Nephi may have allowed small amounts of bitterbrush and sagebrush seed to germinate and go undetected (however, rabbitbrush seed should have responded similarly) and 2) there may have been a soil-borne pathogen at Nephi that may have damaged some of the bitterbrush and sagebrush seed and made it non-viable and not affected rabbitbrush seed.

Furthermore, this study demonstrated that sagebrush and rabbitbrush seed began to germinate under snowpack and then germinated rapidly after snowmelt, whereas bitterbrush seed also began to germinate under snowpack, but spread its germination out over a longer time period.

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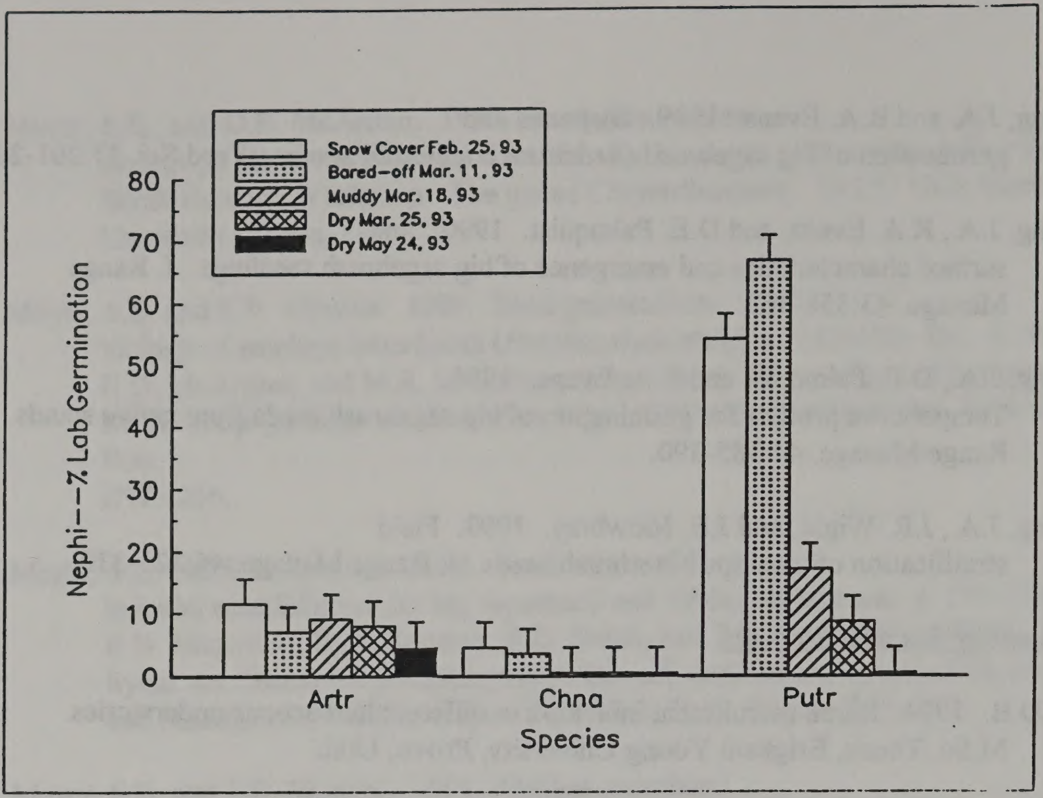

Figure 1a

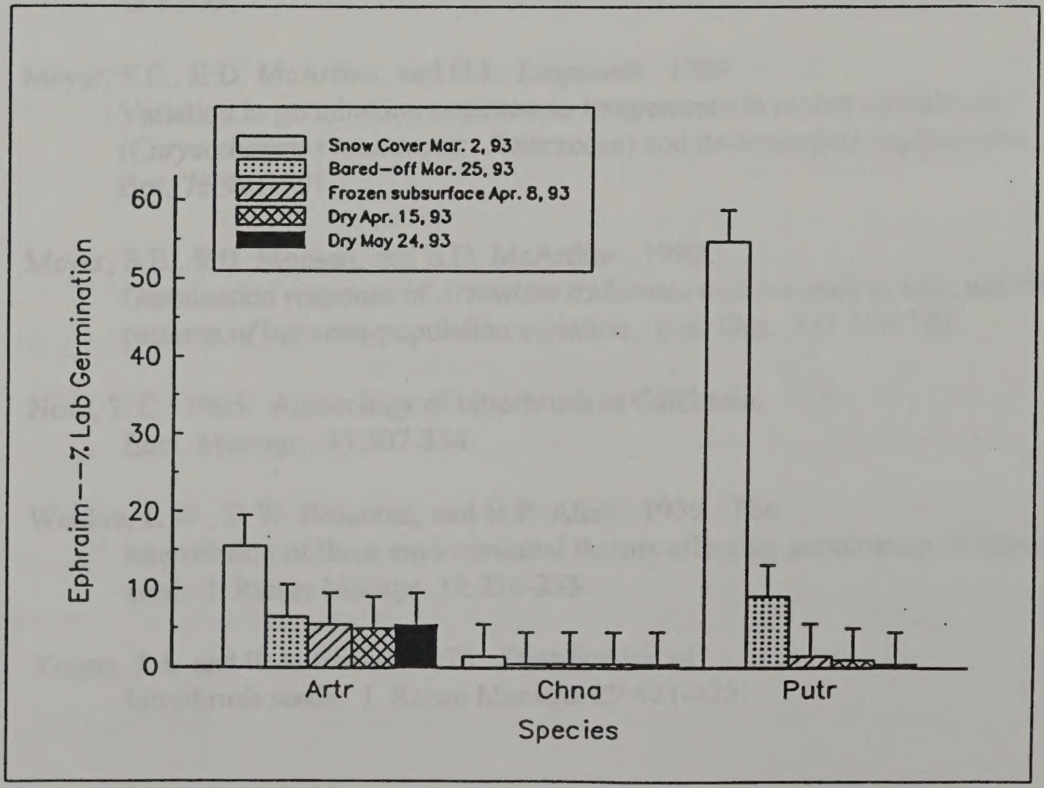

Figure 1b

Table 1. Field germination percentages for mountain big sagebrush, rubber rabbitbrush, and antelope bitterbrush at the Nephi site over five seedbag retrieval dates.

	2/25/93	3/11/93	3/18/93	3/25/93	5/24/93
Mountain Big Sagebrush	33.0	56.5	53.0	51.5	0.0
Rubber Rabbitbrush	50.0	58.5	56.0	51.5	0.0
Antelope Bitterbrush	7.0	10.5	51.0	56.5	0.0

Table 2. Field germination percentages for mountain big sagebrush, rubber rabbitbrush, and antelope bitterbrush at the Ephraim site over five seedbag retrieval dates.

	3/2/93	3/25/93	4/8/93	4/15/93	5/24/93
Mountain Big Sagebrush	42.0	69.5	22.0	24.5	0.0
Rubber Rabbitbrush	44.0	58.5	36.5	39.5	0.0
Antelope Bitterbrush	25.0	66.0	79.0	78.5	0.0

Establishment of Native Cool Season Perennial Grasses on Cheatgrass Rangelands

Nancy L. Shaw and Stephen B. Monsen

Problem

Excessive grazing, invasion of alien annuals, and resultant and drastic increases in wildfire frequency have transformed great expanses of the sagebrush zone into annual rangelands with adverse impacts on associated resource values (Pellant 1990). In 1994 Pellant and Hall reported that 1.3 million ha of U.S. Department of the Interior, Bureau of Land Management lands were dominated by cheatgrass (Bromus tectorum L.) or medusahead wildrye (Taeniatherum caput-medusae ([L.] Nevsiki) and another 30.8 million ha were classified as infested or susceptible to invasion by the two grasses. Early revegetation efforts emphasized use of exotic perennial grasses capable of competing with the annuals (Pellant and Monsen 1993). However, problems associated with monocultures and recent emphasis on multiple use, biodiversity, and conservation of biological resources have created a need to develop technology for incorporating a wide array of native species into revegetation plans (Pellant and Monsen 1993; Pyke and Archer 1991; Roundy and others 1997). Reestablishment of native perennial grasses on rangelands dominated by cheatgrass and other annuals is generally unsuccessful due to the competitive ability of the annuals (Call and Roundy 1991; Young and Allen 1997). Improvement of artificial seeding success requires modification of site preparation and seeding practices to create favorable seedbed conditions for germination and seedling establishment. One approach to this problem is to increase the number of seeds planted to improve the probability that seeds will be introduced into suitable microsites. Another is to use alternative seeding techniques to create favorable microsites. The objective of this study was to examine the emergence and establishment of three cool season native perennial grasses in response to seeding rate and seeding method on cheatgrass infested rangelands.

Materials and Methods

Planting Sites

Three cheatgrass dominated sites were selected for study, Lucky Peak and the Orchard Research Area (Orchard) in the sagebrush zone of southwestern Idaho and Pigeon Hollow in the pinyon-juniper zone of central Utah (Table 1). All three were dominated by cheatgrass and other annuals.

Precipitation and air temperature were measured continuously at the U.S. Department of Agriculture, Forest Service, Lucky Peak Nursery about 2 km north of the Lucky Peak study site, at the Orchard Site (U.S. Department of Agriculture, Agricultural Research Service weather station), and at Sorensens Field (Utah Division of Wildlife Resources weather station) about 13 km north of the Pigeon Hollow site.

Seedbed Preparation

At each site two 20- by 18-m^2 plot grids were installed in fall 1994, one for the seeding rate study and one for the seeding methods study. Two additional grids were installed and both studies were again planted at each site in fall 1995. Seedbeds were prepared by twice-over rototilling to a depth of about 10 to 15 cm. Individual plots were 1 m^2 with 1 m buffer zones between plots.

Seeded Species

Three species were seeded in each plot grid at each site. An effort was made to use local seed sources when they were available. At Orchard and the Lucky Peak site the species and seed sources were:

(1) Snake River wheatgrass (Elymus lanceolatus (Scribn. & Sm.) Gould spp. wawaiensis), Enterprise, Oregon (1993 seedlot produced in a seed field at Spanish Fork, Utah).

(2) Sandberg bluegrass (Poa secunda Presl.) (Released variety 'Canbar' [formerly P. canbyi {Scribn.} Howell], 1994 seedlot).

(3) Bottlebrush squirreltail (Elymus elymoides [Raf.] Swezey) collected from native stands at the Orchard site in 1993.

Bluebunch wheatgrass (Pseudoregneria spicata [Pursh] A. Love) collected at the Provo Overlook, Utah in 1994 was substituted for Snake River wheatgrass at the Pigeon Hollow

Site. Viability of each seedlot was determined each year by tetrazolium chloride testing for use in pure live seed (PLS) calculations.

Rate Study

Seeds of each species were planted at three rates: 66, 328, or 1,312 PLS m^{-1}. Five furrows, 1-m long and about 20 cm apart, were created in each plot with a mechanical imprinter and seeds were distributed along each furrow by hand, covered with soil, and compacted. All rows within a plot were seeded to a single treatment combination (species x seeding rate). Control plots were not seeded. Plots were arranged in a completely randomized design with five replications.

Seeding Methods Study

Seeds of each species were planted using one of three methods:

(1) Single row seeding. Plots were seeded as described for the seeding rate study with 330 seeds planted in each 1-m row.

(2) Double row seeding. Plots each contained five pairs of double rows with the rows in each pair about 5 cm apart. Each of the double rows was planted with 330 PLS as described for the seeding rate study.

(3) Broadcast seeding was accomplished by hand distributing 1,650 PLS over the surface of the entire 1 m^2 plot followed by light raking.

Thus 1,650 PLS were planted in each single-row or broadcast seeding plot, but 3,300 PLS were planted in each double-row seeding plot. Control plots were not seeded. Plots were arranged in a completely randomized design with five replications.

Stand Evaluation and Competition

Density of emerging and establishing seeded grasses in each plot was determined on two counting dates during the first spring following planting. Density of established seeded grass plants was determined by making one count in late spring during the second growing season after seeding. Thus emergence counts for the 1994 planting were made in early and late spring 1995 and establishment counts in late spring 1996. Emergence counts for the 1995 planting were made in early and late spring 1996 and establishment counts in late spring 1997. Ground cover of competing species on each counting date was determined using a point technique.

Statistical Analyses

Effects of planting date, species, and seeding rate or seeding method on seedling density were evaluated by analyses of variance. The square root transformation was used to normalize seedling counts. Data were analyzed separately by year, planting site, and counting date due to differences in counting dates, phenological development between years and sites, and sampling constraints imposed by weather conditions. Means were separated by Fisher's least significant difference. All differences reported are significant at $P<0.05$. Means and standard errors were calculated for ground cover provided by dominant species and major categories of competing vegetation at each site (total annuals, total perennials, and total vegetation).

Results

Environmental Site Conditions

All three sites are characterized by cold winters and hot summers with high temperatures sometimes reaching 40°C. Most precipitation falls in winter and spring.

Lucky Peak. Daily minimum temperatures below 0°C occurred at least itermittently from November through late March or early April at this site each winter, and almost nightly from December through January or early February (Figure 1). Lowest minimum temperatures were in the -10 to -15°C range in 1994-95 and 1996-97, but dropped below -20°C for four nights in 1995-96. October plus November precipitation totaled 93 mm in 1994 compared to 142 mm in 1995 (Figure 1). December to March precipitation was similar in 1994-95 (256 mm) and 1995-96 (248 mm), but greater in 1996-97 (369 mm) due to heavy rains in late December.

Orchard. At this site daily minimum temperatures below 0°C occurred at least intermittently from mid October through late March or early April and almost nightly from November through January or early February (Figure 2). Lowest minimum temperatures were in the -15 to -25°C range each year. As at Lucky Peak, October plus November precipitation was less in 1994 (67 mm) compared to 1995 (83 mm) (Figure 2). December through March precipitation was 104 mm in 1994-95, 170 mm in 1995-96, and 107 mm in 1996-97.

Pigeon Hollow. This site was located at a greater elevation than the other two sites and was colder and drier. Daily minimum temperatures were below 0°C almost nightly from October through April each year. Lowest minimum temperatures were less than -15°C each year (Figure 3). October plus November precipitation totaled 119 mm in 1994-95, but only 13 mm in 1995-96 (Figure 3). December through March precipitation was 107 mm in 1994-95, 145 mm in 1995-96, but considerably greater in 1996-97 (200 mm). Unusually heavy May precipitation occurred in 1995 (108 mm).

Seeding Rates

1994 Seedings. Following a dry fall in 1994, seedlings emerged in early spring 1995 at all three sites as minimum daily soil temperatures rose above freezing. Emergence (March) and establishment (May) of all three species were significantly increased by successively higher seeding rates at Lucky Peak and Orchard (Table 2). May establishment at the high rate ranged from 8 to 15 times the low rate at Lucky Peak and from 5 to 13 times the low rate at Orchard. March and May 1995 seedling density at both locations was greater for Snake River wheatgrass and Sandberg bluegrass than for bottlebrush squirreltail on plots seeded at the moderate and high seeding rates (Table 2). On both dates, Sandberg bluegrass density exceeded that of Snake River wheatgrass on Orchard plots seeded at the high rate. Seedling densities of all species were similar at the low seeding rate in March and in May 1995.

At Pigeon hollow, March 1995 bluebunch wheatgrass density was improved only by seeding at the high rate; emergence of Sandberg bluegrass was greater at successively higher seeding rates; and bottlebrush squirreltail density did not respond to increases in seeding rate (Table 2). Density was greatest for Sandberg bluegrass compared to the other two species at the moderate and high rates, but did not vary among species when seeded at the low rate.

After two growing seasons (May 1996), seeded grass density at Lucky Peak and Orchard varied with seeding rate and species (Table 2). At Lucky Peak, density of Snake River wheatgrass plants increased with seeding rate, while density of Sandberg bluegrass plants was improved equally by seeding at either the moderate or high rate compared to the low rate. At Orchard, density was improved by seeding Snake River wheatgrass at the high compared to the low seeding rate, and Sandberg bluegrass at the high compared to the low or moderate seeding rates. Poor establishment of bottlebrush squirreltail at both sites was not related to seeding rate. At Pigeon Hollow, few seeded grass plants survived with no differences attributable to seeding rate or species.

1995 Seedings. At both Lucky Peak and Orchard, seedlings emerged in late fall in response to October and November precipitation and favorable temperatures for germination. Late April 1996 density of emerged seedlings generally increased with each seeding rate increase for all species (Table 3). By late May 1996, however, this trend was apparent only for Snake River wheatgrass. Density of surviving Sandberg bluegrass seedlings was greatest on plots seeded at the high rate at Lucky Peak, but did not vary with seeding rate at Orchard. Late May 1996 density of bottlebrush squirreltail was enhanced by seeding at the high, but not at the moderate seeding rate at both sites. In late April and late May 1996, seedling density exhibited little variation among species on plots sown at the low rate at Lucky Peak or Orchard (Table 3). On both dates, density was generally greater for Snake River wheatgrass compared to the other two species when sown at the moderate or high rates.

At Pigeon Hollow, seedling density was greatest on plots seeded at the high rate in April and May 1996, but did not differ among species (Table 3). Seedling emergence and establishment at this location did not exceed 3% of planted seed for any treatment.

After two growing seasons, plant density varied with species and seeding rate at Lucky Peak and Orchard (Table 3). At Lucky Peak, density of Snake River wheatgrass and Sandberg bluegrass were enhanced by seeding at the high rate. At Orchard, Sandberg bluegrass density was similarly improved by seeding at the moderate and high rates. No plants of any seeded species survived at Pigeon Hollow.

Seeding Methods

1994 Seedings. Seedling density varied by species and seeding method in both late March/early April and in May 1995 at Lucky Peak and Orchard (Table 4). Snake River wheatgrass and Sandberg bluegrass density was greatest in double-row seedings, intermediate on single-row seedings, and least on broadcast plots. Density of bottlebrush squirreltail varied with seeding method at both sites in late March/early April 1995, but by May 1995 density was enhanced only by double-row seeding at Orchard. At Pigeon Hollow density of bluebunch wheatgrass and Sandberg bluegrass did not vary with seeding method in late March. Both broadcasting and double row seeding enhanced density of bottlebrush squirreltail compared to single row seeding.

At Lucky Peak density was greatest for Sandberg bluegrass followed by Snake River wheatgrass, then bottlebrush squirreltail for all seeding methods in late March/early April and in May 1995 (Table 4). The pattern was similar at Orchard except Snake River wheatgrass and Sandberg bluegrass densities were similar in early spring on double row seedings and on both dates for broadcast seedings. At Pigeon Hollow, density of Sandberg bluegrass exceeded that of bottlebrush squirreltail for all seeding methods. Bluebunch wheatgrass density was intermediate between and similar to the other two species.

By early May 1996, plant density varied with species and seeding method at Lucky Peak (Table 4). Seeding in either single or double rows produced greater Snake River wheatgrass densities than broadcast seeding. Greatest Sandberg bluegrass densities resulted from single-row or broadcast seeding; seeding method did not affect second-year density of bottlebrush squirreltail. Density was greatest for Snake River wheatgrass, followed by Sandberg bluegrass, then bottlebrush squirreltail on single and double row seedings. Density of Snake River wheatgrass and Sandberg bluegrass were similar on broadcast seeded plots and exceeded bottlebrush squirreltail density.

Density of established seedlings differed among species, but did not vary with seeding method at Orchard or Pigeon Hollow (Table 4). Density was greatest for Sandberg bluegrass at Orchard and for bluebunch wheatgrass at Pigeon Hollow.

1995 Seedings. Seeding density varied with species and seeding method on each 1995 counting date at Lucky Peak and Orchard (Table 5). At Lucky Peak, Snake River wheatgrass densities were greatest on double-row seedings, followed by single-row, then broadcast seedings in both May and June 1996. Sandberg bluegrass and bottlebrush squirreltail emergence were greatest on double-row seedings and least on broadcast seedings in May, but density of both species did not differ with planting method in June. At Orchard, more seedlings emerged from double-row seedings of Snake River wheatgrass and Sandberg bluegrass than from single-row or broadcast seedings by late

April. This pattern persisted for Snake River wheatgrass in late May, but density of Sandberg bluegrass seedlings no longer differed among seeding methods. Density of bottlebrush squirreltail did not vary with seeding method on either date. Seedling densities were generally greatest for Snake River wheatgrass and least for bottlebrush squirreltail at both sites on both counting dates.

Mid-April 1996 emergence of all species at Pigeon Hollow was greatest from broadcast seedings and did not differ between single and double-row seedings (Table 5). By late May 1996 seedling density did not vary by seeding method or species.

After two growing seasons, density varied with species and seeding method at Lucky Peak (Table 5). In May 1997 density of Snake River wheatgrass was greater on single-and double-row seedings than on broadcast seedings, while density of Sandberg bluegrass and bottlebrush squirreltail did not vary with seeding method. Density was greater for Snake River wheatgrass than the other two species on single-and double row seeded plots. Density did not vary among species on broadcast seedings. At Orchard, seeding method did not affect density of any species. Density was greater for Sandberg bluegrass than for the other two species. No seeded grasses survived at Pigeon Hollow by July 1997.

Competing Species

1994 Seeding Rate and Seeding Method Studies. Competing vegetation on both the seeding rate and seeding methods study grids at Lucky Peak was dominated by cheatgrass and bulbous bluegrass in 1995 and in 1996 (Tables 6 and 7). Total ground cover provided by competing vegetation on both plots was less than 15 percent in March 1995, but exceeded 50 percent by May 1995 and 65 percent by May 1996.

At Orchard, competing vegetation on both study grids in March and May 1995 was dominated by bur buttercup (Tables 6 and 7). Total competing vegetation provided more than 50 percent ground cover by March 1995 and more than 70 percent by May 1995. By May 1996, dominance had shifted to cheatgrass and total competing vegetation exceeded 55 percent on both grids. Cover provided by bur buttercup had declined to less than 1 percent.

Competing vegetation was very sparse on both study grids at Pigeon Hollow and did not exceed 10 percent in either 1995 or 1996 (Tables 6 and 7). Cheatgrass was the dominant species in both years.

1995 Seeding Rate and Seeding Method Studies. Development of competing species on both 1995 study grids at Lucky Peak followed the same pattern noted for the 1994 study grids (Tables 8 and 9). Both grids were dominated by cheatgrass and bulbous bluegrass (Poa bulbosa L.). Total ground cover produced by competing species exceeded 60 percent in late April and mid May 1996. After two growing seasons, both grids remained dominated by the annual grasses with total competing ground cover exceeding 50 percent.

At Orchard the 1995 grids were dominated by cheatgrass during both the first and second growing season following planting (Tables 8 and 9). Ground cover produced by bur buttercup (Ranunculus testiculatus Crantz.) was less than 25 percent on both grids in late April 1996, declining to less than 10 percent thereafter. Total ground cover produced by competing species exceeded 60 percent in both 1996 and 1997.

Cover produced by competing species was again low at Pigeon Hollow during the first season following planting. Mid April and late May 1996 ground cover was dominated by cheatgrass and totaled less than 15 percent. By 1997, however, ground cover on the seeding methods grid was dominated by Russian thistle (Salsola pestifer A. Nels.) (31.3 percent ground cover) and totaled more than 70 percent.

Discussion and Conclusions

If acceptable establishment of seeded grasses after two growing seasons is set at 3 plants per linear meter for the seeding rate study and 16 plants per square meter for the seeding methods study, then all seeding rates and methods provided for adequate establishment (May 1996) of Snake River wheatgrass and Sandberg bluegrass at Lucky Peak and Orchard on plots seeded in 1994 (Tables 2 and 4). Although both Snake River wheatgrass and Sandberg bluegrass emergence and first year establishment were generally greater on double row seedings at both Lucky Peak and Orchard, the advantage was generally lost by the second year.

Establishment of bottlebrush squirreltail was marginally acceptable when it was seeded at the moderate or high rates at Lucky Peak or at the high rate at Orchard.

Acceptable establishment of this species, however, was not obtained in the 1994 seeding method study for any treatment at either site. Established bluebunch wheatgrass densities were adequate on all seeding methods plots in May 1996 Pigeon Hollow. None of the seeding rates or methods were effective in establishing adequate densities of Sandberg bluegrass or bottlebrush squirreltail at this site.

For the seeding rate and seeding methods studies planted in 1995, seeding at the high rate and all three seeding methods provided adequate second year establishment of Snake River wheatgrass at Lucky Peak while all seeding methods provided marginally acceptable stands at Orchard (May 1997) (Tables 3 and 5). Seeding Sandberg bluegrass at the moderate or high rate and use of single or double row seedings provided adequate establishment at Lucky Peak. All seeding rates and methods were effective for this species at Orchard. Densities of bottlebrush squirreltail did not reach adequate levels at Lucky Peak or Orchard regardless of seeding rate or method. No seedlings of any species established at Pigeon Hollow.

In general, establishment of individual species and seed sources was greatest at the sites where they expected to be best adapted. Of the species planted, Snake River wheatgrass appeared more responsive to seeding rate increases and generally produced the greatest densities at Lucky Peak. Mature plants of this subspecies of thickspike wheatgrass are adapted to areas with low precipitation when established. However, the subspecies establishes and grows slowly (Alderson and Sharp 1994), making it susceptible to competition from earlier developing and more vigorous species. Cheatgrass and bulbous bluegrass, dominate competing species at Lucky Peak, begin growth early, and particularly in the case of cheatgrass, produce rapidly developing root systems that utilize available soil water (Harris 1977; Harris and Wilson 1970; Svejcar 1990). Although the Lucky Peak site receives greater amounts of precipitation than the other two sites, its coarse, granitic soils dry rapidly in spring. Reduced density of Snake River wheatgrass, but not Sandberg bluegrass plants resulting from broadcast compared to single-row seeding at Lucky Peak might be explained by the relatively larger seed size of Snake River wheatgrass and a requirement for deeper planting. This pattern, however, was not observed at the other two sites.

Sandberg bluegrass appeared most responsive to increases in the seeding rate and generally established better than the other seeded grasses at Orchard. The variety 'Canbar' (formerly Canada bluegrass) is drought tolerant and was selected for its vigor and rapid spring growth (Alderson and Sharp 1994). Sandberg bluegrass is the dominant perennial native grass on less disturbed areas at Orchard. Bur buttercup along with lesser amounts of cheatgrass were the dominant competing annuals at Orchard. Bur buttercup germinates and begins growth at low temperatures (Young and others 1992). It is shallow rooted, but can compete strongly with germinating seeds for available soil water, often precluding development of other species (Mack 1981)..

Factors contributing to the low establishment of bottlebrush squirreltail at all sites were not determined. It was expected that this early successional species would establish relatively well on the disturbed study sites. The species is highly variable with numerous ecotypes (Clary 1975). However, the seed source planted did not establish well, even when seeded at the Orchard site near its collection area.

Success in establishing bluebunch wheatgrass at Pigeon Hollow was limited, even though the species is a dominate native on less disturbed portions of this area. Neither Sandberg bluegrass or bottlebrush squirreltail established at adequate levels in any of the studies at this location. Competition provided by early developing annuals was low for both the 1994 and 1995 studies. Russian thistle provided considerable cover by July 1997 on the 1995 plots, but this C4 species develops largely after cool season grasses enter summer dormancy. Poor establishment of seeded grasses may have resulted from alkaline soil conditions and frost heaving from seeded rows.

The response of the seeded species appears to support the use of locally adapted species and seed sources. It was expected that bottlebrush squirreltail, an early successional species might have established more readily than the other species tested on these disturbed sites. This hypothesis, however, was not supported by the results.

Seedling emergence of seeded grasses and most competing annuals occurred in spring 1995 from the 1994 plantings at Lucky Peak and Orchard. However, with fall rains and moderate temperatures, emergence of seeded grasses and competing vegetation from the 1995 plantings occurred in fall 1995 soon after the plots were seeded. Fall emergence did not lead to improved establishment of seeded grasses at either site, as weeds also germinated in fall and were able to continue root development at lower temperatures than the perennials (Young and Evans 1982). Although good first year densities of the seeded species developed at both sites, considerable losses occurred by the end of the second growing season indicating the perennials were not capable of developing adequate adventitious root systems or obtaining water and nutrients required for full establishment (Aguirre and Johnson 1991a, b; Melgoza and Nowak 1991; Ries and Svejcar 1991).

Although seeding directly on sites with dense annual competition is not recommended, this work emphasizes the need to develop seeding methodology to create favorable microsites, not only to enhance conditions for germination, but also to minimize competition encountered for developing perennials and to improve water catchment and extend the period of favorable water conditions for growth (Klomp and Hull 1972). This approach maximizes the opportunity for seedlings to establish during the first growing season. Results of this work provide some indication that response to seeding rate or row seeding compared to broadcast seeding may be most pronounced when adequate water is available for development of all species. Dry conditions or low nutrient availability or dense competition that reduces water or nutrient availability contributed to poor stand development or seeding failure regardless of seeding rate or technique. Francis and Archer (1996) recommended use of reduced seeding rates for 'Hycrest' (Agropyron cristatum [L.] Gaertn. X desertorum) and 'Nordan' (A. desertorum [Fish. Ex Link] Schult.) crested wheatgrass to reduce the potential for intraspecific competition. Optimal seeding rates must maximize the opportunity for seeds to encounter favorable microsite conditions, but minimize the probability of interspecific competion in highly variable environments. Development of techniques, whether mechanical or chemical for reducing the interaction of establishing perennials with annual species is required to maximize opportunities for revegetation on drier sites (Lowther and others 1996; Monsen and Kitchen 1994). Following guidelines developed for wildland seedings (Blaisdell and others 1982; Jones 1997; Klomp and Hull 1972; Plummer and others 1968), selection of appropriate planting sites, use of adapted seed sources, and development of effective seeding technology is essential for efficient use of recent and planned releases of native perennial grasses for the sagebrush zone.

Management Implications

Several suggestions or recommendations may be made based on this study and related work:

1. The basic guidelines for rangeland revegetation set forth by Plummer and others (1968) (See also Blaisdell and others 1982) should be followed in determining if, when, and how a site should be seeded.
2. Seeded species were more responsive to differences in the seeding rate or method on the site receiving the greatest precipitation. Thus the seeding rates and techniques employed may be inadequate to overcome adverse plant competition or other unfavorable environmental conditions. Methods for controlling weeds in the vicinity of emerging perennials must be used in conjunction with appropriate seeding rates and seeding techniques to create favorable seedbed conditions for germination of the seeded species.
3. Although moderate to high first year seedling densities of Snake River wheatgrass and Sanberg bluegrass were obtained for seedling densities and methods at Lucky Peak and Orchard, considerable losses occurred after the first growing season. Seedlings must develop adequate leaf areas and adventitious root systems to become fully established during the first growing season. Further research is required to provide useful descriptions of fully established seedlings of commonly used native revegetation species for an array of rangeland conditions. High densities persisting after two years may result in intraspecific competition and self thinning as plants mature.
5. Alkaline conditions and frost heaving on the disturbed site at Pigeon Hollow may require the use of alternative species and seeding methods for reestablishment of revegetation.

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Table 1. Description of grass seeding study sites.

Characteristic	Orchard Research Site	Lucky Peak	Pigeon Hollow
Location	Lower Snake River Plain, southwestern Idaho	Boise Front, southwestern Idaho	Great Basin, central Utah
Native vegetation	Artemisia tridentata var. wyomingensis, Poa sandbergii, Stipa thurberiana	Artemisia tridentata var. vaseyana, Purshia tridentata, Pseudoregneria spicata	Juniperus monophylla, Pinus monophylla, Pseudoregneria spicata, Oryzopsis hymenoides
Disturbance vegetation	Bromus tectorum, Poa bulbosa, Ranuculus testiculatus	Bromus tectorum, Poa bulbosa, Tragopogon dubius	Bromus tectorum, Salsola kali, Ranunculus testiculatus
Elevation (m)	955	1,033	2,088
Mean annual precipitation (mm)	200-300	430	318
Mean annual frost-free days	140-190	126	115-130
Soil	Sandy, mixed, mesic Xeric Torriorthent	Gem Series. Fine, montmorillonitic, mesic, Cumulic Haploxeroll	Quaker Series. Fine-silty, carbonatic, mesic Xeric Torrifluvents

Table 2. Density of grass seedlings by counting date, species, and seeding rate on fall 1994 plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date Species	Seeding rate (PLS m^{-1}) 66	330	1320	Mean
	------seedlings m^{-1}------			
Lucky Peak				
18 March 1995				
Snake River wheatgrass	31A[1]c[2]	109Bb	445Aa	
Sandberg bluegrass	32Ac	175Ab	493Aa	
Bottlebrush squirreltail	13Ac	44Cb	97Ba	
15 May 1995				
Snake River wheatgrass	31Ac	125Ab	491Aa	
Sandberg bluegrass	32Ac	176Ab	495Aa	
Bottlebrush squirreltail	11Ac	37Bb	89Ba	
21 May 1996				
Snake River wheatgrass	27Ac	99Ab	194Aa	
Sandberg bluegrass	4Bb	28Ba	45Ba	
Bottlebrush squirreltail	1Ba	4Ca	3Ca	
Orchard				
28 March 1995				
Snake River wheatgrass	43Ac	172Ab	461Ba	
Sandberg bluegrass	37Ac	185Ab	650Aa	
Bottlebrush squirreltail	20Ac	66Bb	147Ca	
4 May 1995				
Snake River wheatgrass	35Ac	163Ab	362Ba	
Sandberg bluegrass	34Ac	148Ab	454Aa	
Bottlebrush squirreltail	17Ac	66Bb	147Ca	
7 May 1996				
Snake River wheatgrass	11Ab	24Aab	30Ba	
Sandberg bluegrass	4Ab	22Ab	105Aa	
Bottlebrush squirreltail	1Aa	2Ba	4Ca	
Pigeon Hollow				
28 March 1995				
Snake River wheatgrass	17Ab	21Bb	84Ba	
Sandberg bluegrass	12Ac	73Ab	220Aa	
Bottlebrush squirreltail	10Aa	12Ba	13Ca	
9 May 1996				
Mean				1

[1] Species means within planting site, counting date, and seeding rate followed by the same upper case letter are similar ($P>0.05$).

[2] Seeding rate means within planting site, counting date, and species followed by the same lower case letter are similar ($P>0.05$).

Table 3. Density of grass seedlings by counting date, species, and seeding rate on fall 1995 plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date Species	Seeding rate (PLS m^{-1})			
	66	330	1320	Mean
	seedlings m^{-1}			
Lucky Peak				
30 April 1996				
Snake River wheatgrass	11A[1]c[2]	112Ab	388Aa	
Sandberg bluegrass	14Ac	58Bb	281Aa	
Bottlebrush squirreltail	3Bb	8Cb	49Ba	
20 May 1996				
Snake River wheatgrass	7Ac	60Ab	273Aa	
Sandberg bluegrass	2Ab	5Bb	33Ba	
Bottlebrush squirreltail	1Ab	3Bab	10Ca	
14 May 1997				
Snake River wheatgrass	1Ab	1Ab	19Ba	
Sandberg bluegrass	1Ab	4Ab	35Aa	
Bottlebrush squirreltail	1Aa	0Aa	0Ca	
Orchard				
27 April 1996				
Snake River wheatgrass	22Ac	136Ab	476Aa	
Sandberg bluegrass	22Ac	111Ab	342Ba	
Bottlebrush squirreltail	12Ac	44Bb	86Ca	
25 May 1996				
Snake River wheatgrass	17Ac	112Ab	336Aa	
Sandberg bluegrass	4Ba	8Ba	12Ca	
Bottlebrush squirreltail	16ABb	24Bab	60Ba	
12 May 1997				
Snake River wheatgrass	1Aa	0Ba	1Ba	
Sandberg bluegrass	4Ab	11Aa	13Aa	
Bottlebrush squirreltail	1Aa	1Ba	0Ba	
Pigeon Hollow				
15 April 1996				
Mean	2B	2B	8A	
9 May 1996				
Mean	1B	1B	2A	
9 July 1997				0
Mean				

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[1]Species means within planting site, counting date, and seeding rate followed by the same upper case letter are similar (P>0.05).

[2]Seeding rate means within planting site, counting date, and species followed by the same lower case letter are similar (P>0.05).

Table 4. Density of grass seedlings by counting date, species, and seeding method on fall 1994 plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date Species	Seeding method Single Row	 Double Row	 Broadcast	 Mean
	seedlings m^{-2}			
Lucky Peak				
3 April 1995				
Snake River wheatgrass	451B[1]b[2]	915Ba	212Bc	
Sandberg bluegrass	609Ab	1,213Aa	385Ac	
Bottlebrush squirreltail	124Ca	163Ca	44Cb	
22 May 1995				
Snake River wheatgrass	472Bb	1,007Ba	265Bc	
Sandberg bluegrass	695Ab	1,275Aa	466Ac	
Bottlebrush squirreltail	134Ca	38Ca	48Cab	
16 May 1996				
Snake River wheatgrass	467Aa	453Aa	152Ab	
Sandberg bluegrass	98Ba	44Bb	74Aa	
Bottlebrush squirreltail	8Ca	9Ca	7Ba	
Orchard				
29 March 1995				
Snake River wheatgrass	706Bb	1,625Aa	509Ac	
Sandberg bluegrass	985Ab	1,642Aa	580Ac	
Bottlebrush squirreltail	368Cb	701Ba	295Bc	
9 May 1995				
Snake River wheatgrass	766Bb	1,522Ba	581Ac	
Sandberg bluegrass	975Ab	1,825Aa	546Ac	
Bottlebrush squirreltail	322Cb	598Ca	342Bb	
8 May 1996				
Snake River wheatgrass				25B
Sandberg bluegrass				291A
Bottlebrush squirreltail				3B
Pigeon Hollow				
28 March 1995				
Bluebunch wheatgrass	166ABa	282ABa	182ABa	
Sandberg bluegrass	305Aa	455Aa	292Aa	
Bottlebrush squirreltail	99Bb	200Ba	138Ba	
9 May 1996				
Bluebunch wheatgrass				27A
Sandberg bluegrass				9B
Bottlebrush squirreltail				9B

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[1] Species means within planting site, counting date, and seeding method followed by the same upper case letter are similar (P>0.05).

[2] Seeding method means within planting site, counting date, and species followed by the same lower case letter are similar (P>0.05).

Table 5. Density of grass seedlings by counting date, species, and seeding method on fall 1995 plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date Species	Seeding method Single Row	 Double Row	 Broadcast	Mean
	--------seedlings m^{-2}--------			
Lucky Peak				
1 May 1966				
Snake River wheatgrass	567A[1]b[2]	1,268Aa	160Ac	
Sandberg bluegrass	332Bb	738Ba	216Ab	
Bottlebrush squirreltail	59Cab	83Ca	25Bb	
6 June 1996				
Snake River wheatgrass	443Ab	1,036Aa	125Ac	
Sandberg bluegrass	3Ba	15Ba	6Ba	
Bottlebrush squirreltail	8Ba	18Ba	2Ba	
14 May 1997				
Snake River wheatgrass	187Aa	279Aa	34Ab	
Sandberg bluegrass	12Ba	13Ba	3Aa	
Bottlebrush squirreltail	2Ba	1Ba	2Aa	
Orchard				
22 April 1996				
Snake River wheatgrass	409Ab	1,177Aa	403Ab	
Sandberg bluegrass	315Ab	543Ba	266Ab	
Bottlebrush squirreltail	119Ba	201Ca	96Ba	
28 May 1996				
Snake River wheatgrass	313Ab	963Aa	247Ab	
Sandberg bluegrass	40Ba	19Ca	90Ba	
Bottlebrush squirreltail	65Ba	129Ba	71Ba	
13 May 1997				
Snake River wheatgrass				4B
Sandberg bluegrass				33A
Bottlebrush squirreltail				1B
Pigeon Hollow				
15 April 1996				
Mean	28B	42B	62A	
20 May 1996				
Mean				15
9 July 1997				
Mean				0

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[1] Species means within planting site, counting date, and seeding method followed by the same upper case letter are similar ($P>0.05$).

[2] Seeding method means within planting site, counting date, and species followed by the same lower case letter are similar ($P>0.05$).

Table 6. Percent ground cover (±standard error) produced by competing species by counting date on fall 1994 seeding rate plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date	Competing species				
	Cheatgrass	Bulbous bluegrass	Total annuals	Total perennials	Total vegetation
	% cover				
Lucky Peak					
18 March 1995	2.2±0.3	5.9±0.5	8.6±0.6	0.0	8.6±0.6
15 May 1995	22.1±1.0	20.3±1.0	50.0±1.2	3.7±0.5	53.7±1.2
21 May 1996	26.5±0.9	17.9±0.9	54.9±1.2	16.8±1.1	71.7±1.0
	Cheatgrass	Bur buttercup	Total annuals	Total perennials	Total vegetation
	% cover				
Orchard					
29 March 1995	2.7±0.3	43.9±1.1	52.5±1.1	0.2±0.1	52.7±1.1
4 May 1995	9.6±0.6	49.2±1.0	79.0±0.9	0.0	79.0±0.9
7 May 1996	52.7±1.2	0.1±0.0	63.7±1.1	0.0	63.7±1.1
Pigeon Hollow					
28 March 1995	0.4±0.1	0.1±0.1	0.6±0.1	0.0	0.6±0.1
9 May 1996	4.1±0.7	0.0	4.3±0.7	0.5±0.2	4.7±0.2

Table 7. Percent ground cover (±standard error)produced by competing species by counting date on fall 1994 seeding method plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date	Competing species				
	Cheatgrass	Bulbous bluegrass	Total annuals	Total perennials	Total vegetation
	% cover				
Lucky Peak					
3 April 1995	3.7±3.9	8.3±0.7	13.7±0.8	0.9+0.2	14.6±0.8
22 May 1995	24.5±1.0	13.2±0.9	51.3±1.2	4.4±0.5	55.7±1.2
16 May 1996	33.1±1.0	15.4±0.9	55.9±1.1	12.6±0.9	68.5±1.0
	Cheatgrass	Bur buttercup	Total annuals	Total perennials	Total vegetation
	% cover				
Orchard					
29 March 1995	5.2±0.4	48.2±1.1	58.8±1.1	0.6±0.2	59.4±1.1
9 May 1995	15.2±0.7	41.8±1.0	75.5±1.0	1.0+0.2	76.5±1.0
8 May 1996	44.5±1.2	0.1±0.1	57.3±1.0	1.3+0.4	58.5±1.0
Pigeon Hollow					
28 March 1995	0.7±0.3	0.7±0.3	1.3±0.4	0.1+0.1	1.5±0.5
9 May 1996	3.1±0.5	0.2+0.1	3.4±0.5	2.9±0.5	6.3±0.7

Table 8. Percent ground cover (±standard error) produced by competing species by counting date on fall 1995 seeding rate plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date	Competing species				
	Cheatgrass	Bulbous bluegrass	Total annuals	Total perennials	Total vegetation
	% cover				
Lucky Peak					
30 April 1996	32.2±1.1	29.4±1.1	68.9±1.0	0.8+0.2	69.7±1.0
20 May 1996	31.7±1.2	17.2±1.1	61.1±1.1	5.3±0.6	66.4±1.1
15 May 1997	42.9±1.2	11.2±0.7	73.2±1.1	0.0	73.2±1.1
	Cheatgrass	Bur buttercup	Total annuals	Total perennials	Total vegetation
	% cover				
Orchard					
27 April 1996	45.4±1.0	24.1±0.9	78.4±1.1	0.0	78.4±1.1
25 May 1996	55.4±1.1	9.4±0.6	72.7±1.0	0.0	72.7±1.0
7 May 1997	72.1±1.0	0.0	73.4±1.0	0.0	73.4±1.0
Pigeon Hollow					
15 April 1996	1.4±0.2	0.0	3.0±0.3	0.4+0.1	3.4±0.4
20 May 1996	2.8±0.4	2.2+0.4	5.1±0.6	0.5±0.2	5.7±0.6
9 July 1997	---------	---------	---------	---------	---------

Table 9. Percent ground cover (±standard error) produced by competing species by counting date on fall 1995 seeding method plantings at Lucky Peak and the Orchard Research Site, southwestern Idaho, and Pigeon Hollow, central Utah.

Planting site Counting date	Competing species				
	Cheatgrass	Bulbous bluegrass	Total annuals	Total perennials	Total vegetation
	% cover				
Lucky Peak					
1 May 1996	16.3±0.9	42.4±1.2	61.0±1.1	0.8+0.2	61.8±1.1
6 June 1996	16.9±1.1	45.8±1.2	65.1±1.1	2.0±0.3	67.1±1.0
14 May 1997	26.8±1.0	7.5±0.6	49.4±1.1	0.1±0.1	49.5±1.1

	Cheatgrass	Bur buttercup	Total annuals	Total perennials	Total vegetation
	% cover				
Orchard					
22 April 1996	38.7±1.1	15.5±0.9	75.2±1.1	0.8±0.2	76.1±1.1
28 May 1996	51.4±1.2	4.8±0.5	62.7±1.4	0.2+0.1	62.9±1.4
13 May 1997	66.9±1.3	3.2±0.6	69.2±1.4	0.0	69.3±1.4
Pigeon Hollow					
15 April 1996	4.3±0.5	3.7±0.4	8.2±0.7	0.2+0.1	8.4±0.7
20 May 1996	5.4±0.5	4.9+0.6	10.5±0.9	0.6±0.2	11.2±0.9
9 July 1997	23.4+1.3	4.6+0.5	65.7+1.3	5.8+0.6	71.5+1.0

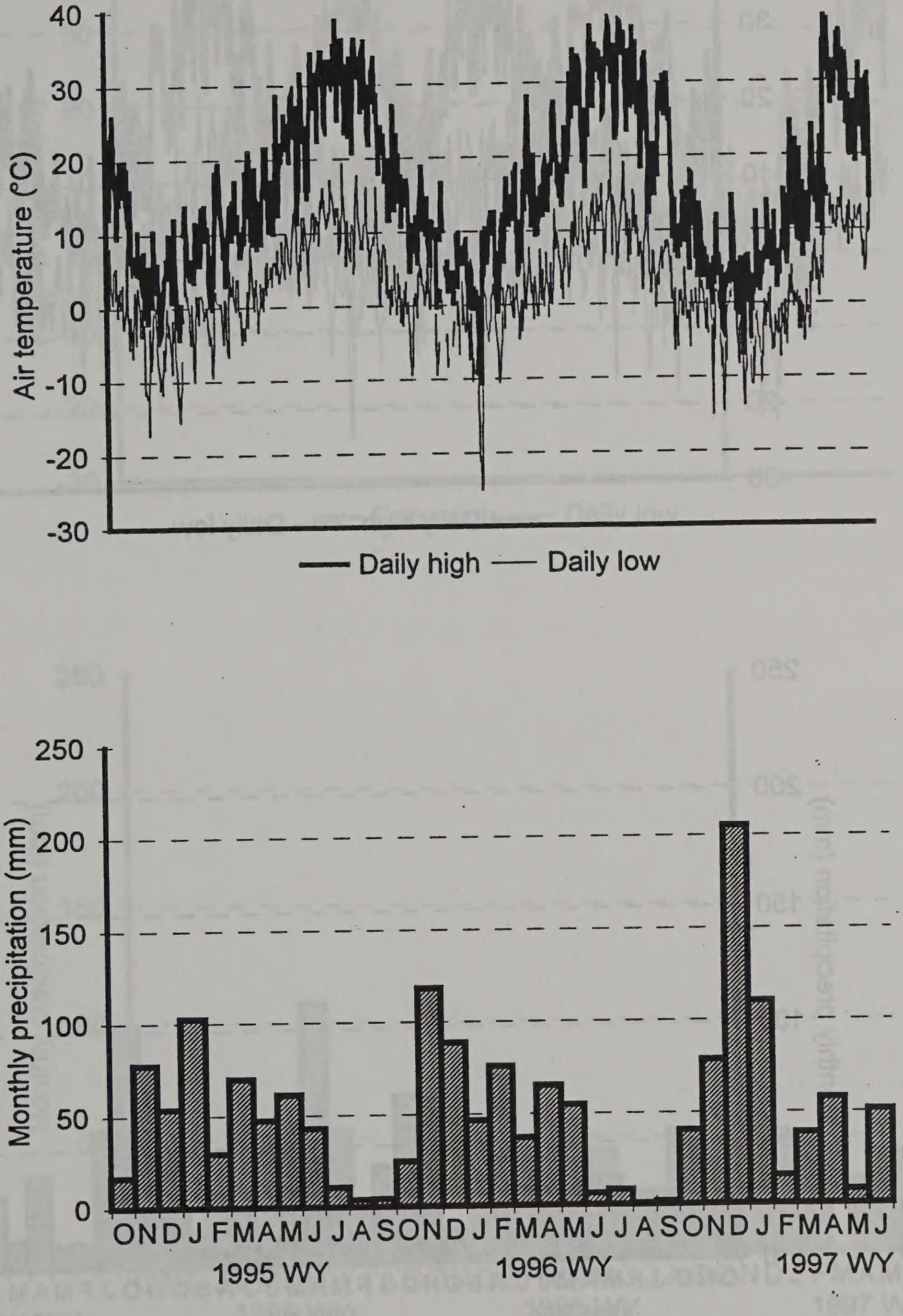

Fig. 1. October 1994 to June 1997 air temperature profile and precipitation, Lucky Peak.

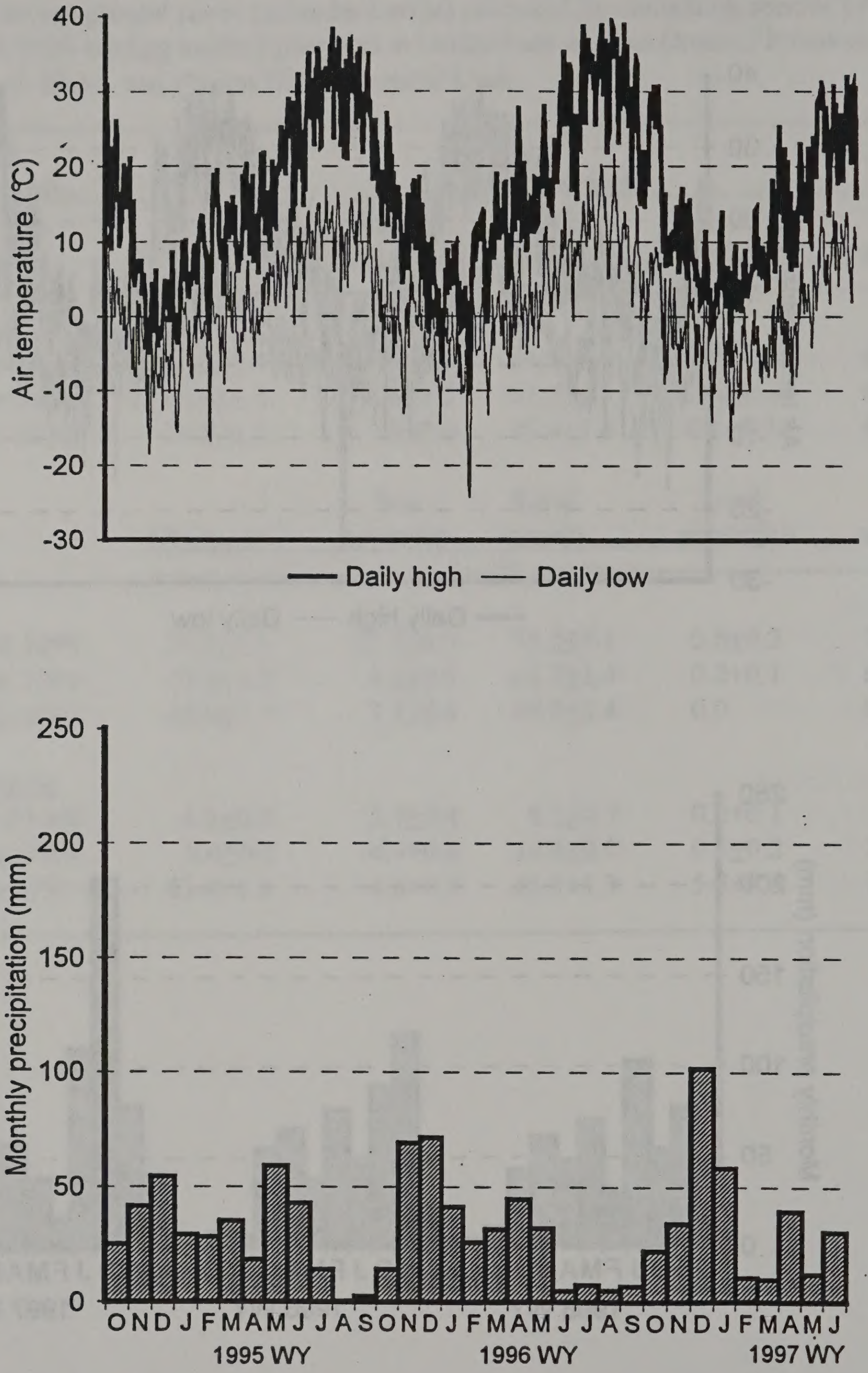

Fig. 2. October 1994 to June 1997 air temperature profile and precipitation, Orchard.

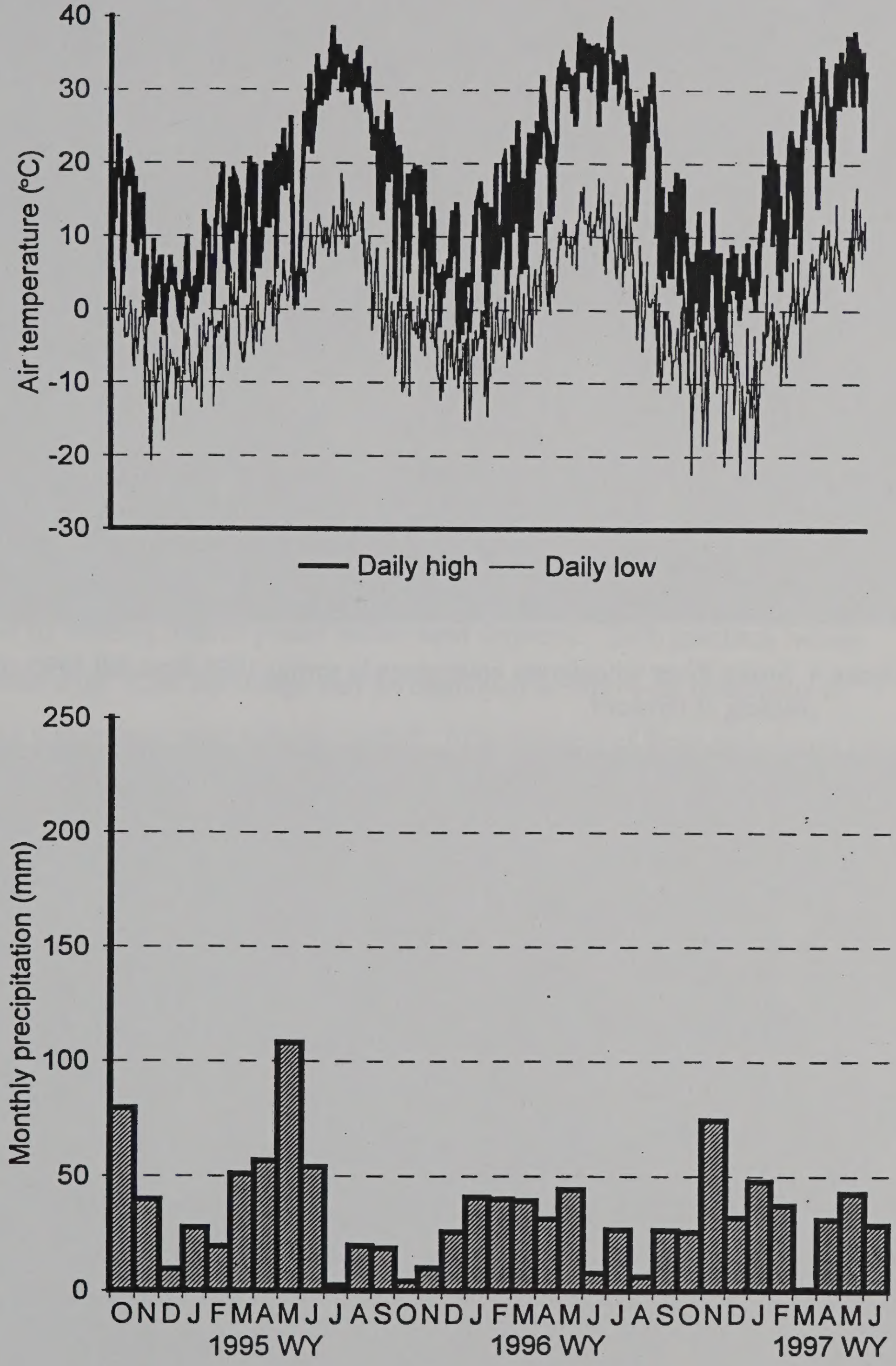

Fig. 3. October 1994 to June 1997 air temperature profile and precipitation, Sorensens Field.

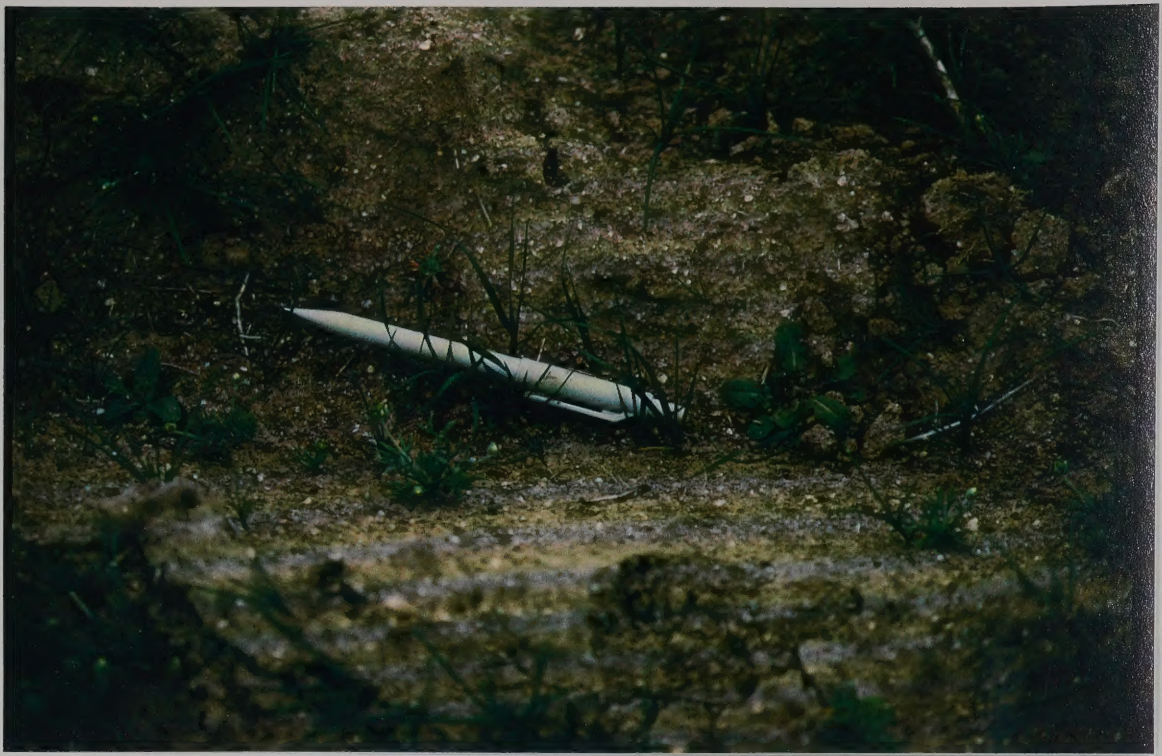

Figure 4. Snake River wheatgrass emergence in spring 1996 from fall 1995 single-row planting at Orchard.

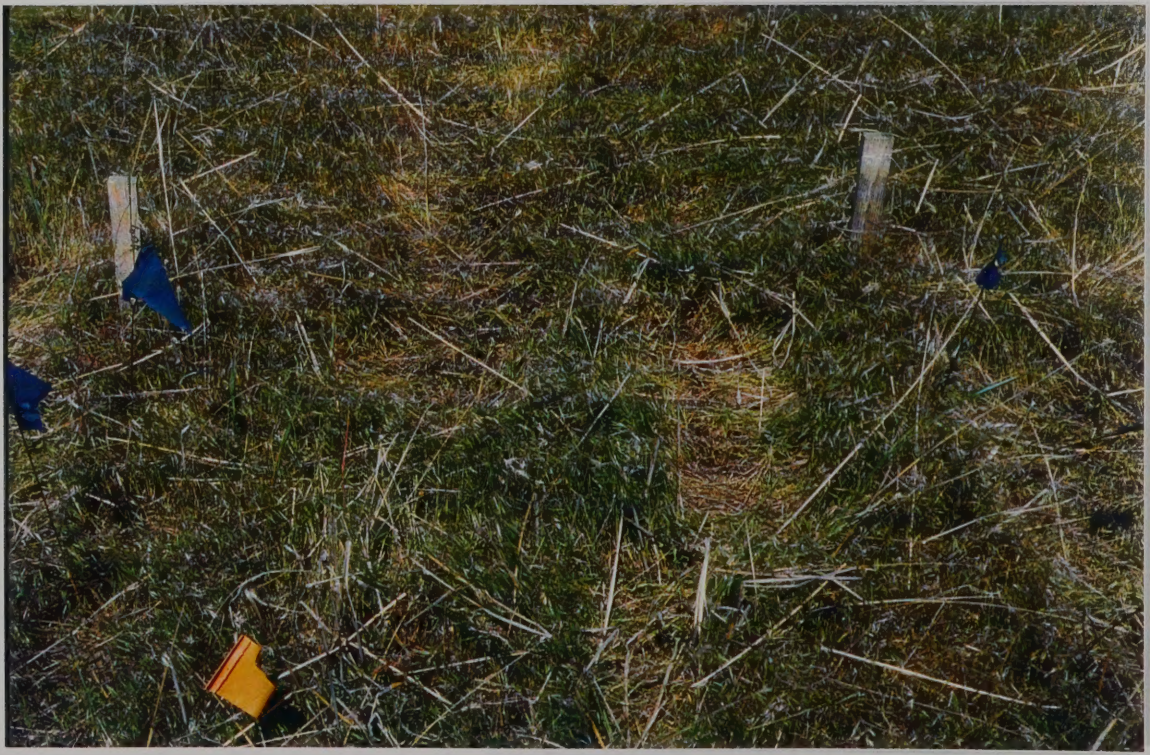

Figure 5. Snake River wheatgrass fall 1995 broadcast seeding at Orchard in spring 1997.

Effectiveness of Oust© Herbicide (Sulfometuron methyl) to Control Exotic Annual Grasses and to Evaluate the Effects of the Chemical on Native and Seeded Species

Stephen B. Monsen and Nancy L. Shaw

Problem

Although considerable information has been developed concerning the ecology competitive ability, management, and revegetation potential of cheatgrass and medusahead communities, effective and reliable measures have not been developed to control their spread or to restore weed-infested sites (Monsen 1994; Monsen and McArthur 1995; Roundy and others 1997; Young and Evans 1970). To be effective, treatments must control germinating seeds, establishing seedlings, and seed production. Cheatgrass competition can sometimes be controlled by spring tillage or by burning mature plants before seed dispersal. Both practices reduce recruitment of a seed crop. Late fall tillage may be employed as follow-up treatments to eliminate seedlings that emerge after autumn rainfall. Effectiveness of these techniques varies widely depending on terrain, local weather conditions, soil water content, treatment timing relative to cheatgrass or medusahead development, and rapid recovery of cheatgrass from residual soil reserves that may be left near the soil surface where they are capable of germinating (Hull and Holmgren 1964; Klomp and Hull 1972; Stewart and Hull 1949; Young and Allen 1997).

Legal restrictions on herbicide use on public lands, public concerns regarding pesticide use, and a lack of chemicals effective for controlling annual grasses, but of low toxicity to nontarget species, generally precluded use of herbicides to control this species until approval of the "Final environmental impact statement for vegetation treatment on BLM lands in thirteen Western states" (USDI 1991) which permitted the use of 21 herbicides on rangelands. One of these herbicides, Oust© (sulfometuron methyl), is an effective pre-emergent and post-emergent herbicide when applied at low levels (≤1 oz/acre). Toxicity and persistence are low, and its effects are most pronounced on actively growing meristematic tissue. Thus although it will kill germinating annuals and perennials at low application rates, its impacts on established perennials are generally minor (DuPont 1996, 1997). Its reported half-life in soil is 20 to 100 days depending upon soil pH and precipitation. Although approved for use on rangelands, a number of questions are unanswered relative to minimum effective application rates and dates, longevity in the soil, effects on common revegetation species seeded in the fall following Oust© treatment the preceding fall or spring, and its effects on nontarget organisms. Consequently, a series of studies was initiated in 1996 to begin addressing these questions and concerns.

Studies

I. Effects of Oust© Herbicide Application Rate and Date on Cheatgrass and Medusahead Monocultures: Preliminary Results

Objective

To investigate the effects of rate and date of Oust© herbicide (sulfometuron methyl) application on control of cheatgrass (Bromus tectorum L.) and medusahead (Taeniatherum caput-medusae [L.] Nevsiki).

Materials and Methods

Planting Sites

The effects of Oust© on these two exotic annual grasses are being tested at two sites within the sagebrush zone of south central Idaho. The Orchard Research Site (Orchard) is about 32 km southeast of Boise, Idaho is dominated by cheatgrass, while medusahead dominates the Lucky Peak site about 25 km east of Boise (Table 1). Both sites are vegetated by near monocultures of the annuals as a result of past livestock grazing practices and wildfires.

Precipitation and air temperature are measured continuously at the Orchard site (U.S. Department of Agriculture, Agricultural Research Service weather station) and at the U.S. Department of Agriculture, Forest Service, Lucky Peak Nursery about 6 km northwest of the Lucky Peak site.

Herbicide Application and Annual Grass Evaluation

A grid of seventy 4 m x 4 m plots was established at each site in fall 1996. Plots were separated by 1 m buffer strips. Oust© was applied to separate plots in fall 1996 and spring 1997 at rates of 0.00, 0.25, 0.50, 0.75, 1.00, 1.25, and 1.50 oz/acre at Orchard and 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 oz/acre at Lucky Peak (Table 2). Higher rates were used on the medusahead site due to greater litter accumulations. Additional grids were established at each site in fall 1997 and plots were treated at the above rates in fall 1997 and spring 1998 (Table 2). Herbicide was applied using a hand-operated, small-plot precision sprayer. Treatments were arranged in a completely randomized design with five replications. Phenological stage of the annual grass was noted and litter and soil water were sampled at the time of each treatment.

Two randomly located 0.06 m^2 subplots in each plot were clipped to a 2 cm stubble height at the time of peak annual grass production (29 May to 2 June 1997 at Orchard; 3-10 July 1997 at Lucky Peak) and dried at 100ºC for 24 hours to provide a measure of biomass production. Seeds produced during the current year were harvested from two additional randomly located 0.06 m^2 subplots in each plot. Seed samples were dried and the seeds separated from the debris. Subsamples of 50 seeds from each subplot were weighed for determination of seed weight. Another subsample of 50 seeds from each subplot was incubated at 20/10ºC (16 hrs/10 hrs) with exposure to cool-white fluorescent light (PAR=15 $\mu M\ m^{-2}\ s^{-1}$) during the high temperature periods. Cheatgrass seeds were dusted with tetramethylthiuram disulfide to control fungal development. Seedlings were considered normal if all structures essential for development were present and the radicle was 5 mm long. Seeds failing to germinate after 28 days were tested for viability using tetrazolium chloride staining (Moore 1985). All seeds from the subplot, if fewer than 50, were used for seed weight determination and germination testing. Biomass and seed crop sampling from the plot grid installed in 1996 at each site will be repeated in 1998. Grids installed in 1997 will be sampled in 1998 and 1999.

Statistical Analyses

The effects of treatment date and rate on biomass production, viable seed weight, total percent germination, and density of viable seeds produced were analyzed by analyses of variance. Viability data were transformed using the arcsin transformation; seed counts were normalized using the square root transformation (Snedecor and Cochran 1980). Means were separated by Fisher's least significant difference. All differences reported are significant at $P \leq 0.05$. Standard errors are presented with grand means.

Results

Application Conditions

Orchard. At the time of the fall 1996 herbicide application (6 Nov.) some cheatgrass seeds were germinating in the litter and surface soil. Although the soil was dry at this time, 119 mm of rain fell between 18 and 24 November 1996 and there was measurable precipitation on 54 days between 18 November 1996 and 4 February 1997 (Figure 1).

Cheatgrass seedlings were in the fourth to sixth leaf stage of growth and had not yet reached the boot stage on the spring 1997 herbicide application date (8 April). Thirteen millimeters of rain fell on this date with an additional 117 mm falling between 17 and 23 April 1997 (Figure 1). However, rainfall was limited from late April through May .

Lucky Peak. Considerable medusahead germination was occurring on the fall 1996 application date (6 Nov.). Soil was dry, but 72 mm of rain fell from 12 to 22 November 1996 (Figure 2). February and March were quite dry; 48 mm of rain fell from 18-23 April following the spring 1997 application on 8 April, but as occurred at Orchard, little precipitation fell from late April through May.

Biomass

Orchard. Biomass production in 1997 varied with application date (P<.0000). Plots treated in fall (including controls) produced 127.1 kg/ha cheatgrass while spring treated plots produced 300.4 kg/ha. Biomass also differed with application rate. Control plots produced 660.4 kg/ha while plots treated at 0.25 to 1.5 oz/acre plots produced 138.8 kg/ha (P<.0000).

Lucky Peak. Biomass production in 1997 varied with application date (P<.0000) and with application rate (P<.0000). Fall treated plots (including controls) produced 145.9 kg/ha while spring treated plots produced 609.4 kg/ha. Control plots produced 1,256.3 kg/ha while plots treated at 0.5 to 3.0 oz/ acre produced 196.6 kg/ha.

Seed Production and Quality

Orchard. No seeds were produced on plots treated at the 0.5 oz/acre or greater rates in fall. Consequently only plots treated at the 0 and 0.25 oz/acre level in fall or spring could be compared. Seed weight (1.6±0.04 mg) did not vary among these treatments, nor did total percent germination (56±6%). Production of viable seeds did differ with seeding rate (P=.0136). There were 3,205 seeds/m^2 on control plots and 436 seeds/m^2 on those treated at the 0.25 oz/acre rate.

Quality of seeds produced on all spring-treated plots (0 to 1.5 oz/acre) was analyzed separately. Seed weight (1.5±0.1 mg) did not vary with treatment level (P=.5017), nor did total percent germination (54±4) (P=.7801). Viable seed production on plots treated at rates from 0.5 to 1.5 oz/acre was reduced 89% compared to controls (P=.0429) (Figure 3). Seed production on plots treated at 0.25 oz/acre was intermediate and did not differ from the other treatments.

Lucky Peak. Plots receiving treatments of 1 oz/acre or greater in fall produced no seed. Consequently only plots treated at the 0 and 0.5 oz/acre level in fall or spring could be compared. Seed weight (4.9± 2.6 mg) and total percent germination (87±3%) did not differ among these treatments. Number of viable seeds/m^2 differed with season of application (P=.0232); there were 3,275 seeds/m^2 on fall treated plots compared to 8,888 seeds/m^2 on spring treated plots. Seed production also varied with application rate (P<.0000). Control plots produced 9,204 seeds/m^2 while plots treated at the 0.5 oz/acre rate produced 2,959 seeds/m^2.

Comparisons of spring treated plots indicated that seed weight (4.7±0.2 mg) (P=.0639) and germination (86±3%) (P=.1013) did not differ with application rate. Density of viable seeds produced, however, was greater for the control than for the remaining treatments (P=.0122) (Figure 3). An exception was the 1.5 oz/acre treatment (5,272 seeds/m^2) which was intermediate between the control and remaining treatments and did not differ from them.

Discussion and Conclusions

First year data indicates a single late fall Oust© application at rates of 0.5 to 1.5 oz/acre on the cheatgrass dominated site or 1.0 to 3.0 oz/acre on the medusahead dominated site did eliminate the all germinating seedlings during the following spring. At both study locations the soil was dry at the time of treatment, annual grasses were germinating, and the herbicide treatment was followed by at least 70 mm of rain within 3 weeks of application. Application of Oust© at 0.25 oz/acre on cheatgrass or 0.5 oz/acre on medusahead reduced but did not eliminate annual grass growth and seed production.

Spring treatments were applied during a dry spring after grasses had reached the 4th to 6th leaf stage. However, more than 40 mm of rain fell at each site during the 3 week period following herbicide application. Although spring treatments of 0.5 to 1.5 oz/acre on cheatgrass and 0.5 to to 3.0 o z/acre (with the exception of the 1.5 oz/acre treatment), on medusahead reduced seed production below control levels, adequate viable seed was produced to provide competition during the next spring which could interfere with establishment of revegetation species. Treatments at rates of 0.25 oz/acre on cheatgrass and 1.5 oz/acre on medusahead did not significantly reduce seed production between control levels.

Management Implications

Oust© herbicide can be used at low application rates to control cheatgrass and medusahead. Treatment impacts on the target species are dependent upon its phenological stage and environmental conditions; further work is required to better describe effective treatment conditions. A better understanding of the herbicides impacts on associated soil microorganisms, established perennials, and revegetation species seeded in fall following treatment is essential to formulate guidelines for safe and effective use of the herbicide.

II. Effect of Oust© Herbicide Treatments on Establishment of Commonly Seeded Revegetated Species.

Objective

To determine the effect of residual Oust© on emergence and establishment of common revegetation species seeded in fall following herbicide treatments applied the previous fall or spring.

Materials and Methods

The 1996 and 1997 plot grids at Orchard and Lucky Peak described in Study I are being used for this study. Seeds of five commonly used native and introduced revegetation species were planted in fall 1997 on all plots of the 1996 grid, approximately 13 months after the fall 1996 treatment and eight months after the spring 1997 treatment. The same species will be planted on the 1997 grid at each site in fall 1998. The seeded species used were:

Scientific Name	Common Name	Seed Source
Agropyron cristatum	Crested wheatgrass	'Ephraim' (commercial)
Pseudoregneria spicata	Bluebunch wheatgrass	'Secar' (commercial)
Achillea millefolium	Yarrow	Eagle, Idaho
Medicago sativa	Alfalfa	'Rambler'
Artemisia tridentata ssp. wyomingensis	Wyoming big sagebrush	Snake River Birds of Prey Area, Idaho

Five 1-m long furrows were created in each plot including the nontreated controls. Each of the five species was hand seeded in a separate furrow at the rate of 66 pure live seeds/m, covered with soil, and compacted lightly. Crested wheatgrass and bluebunch wheatgrass were covered with about 0.5 to 1 cm of soil; seeds of the remaining species were covered very lightly. Species were randomly assigned to the furrows in each plot. Orchard was seeded on 2 December 1997 and Lucky Peak on 3 December 1997.

Density of emerging and establishing seedlings of each seeded species will be determined on at least two counting dates in spring 1998 and once in late spring 1999 for seedings on the 1996 grid and in spring 1999 and 2000 for seedings on the 1997 grid. Biomass of seeded species will be sampled after two growing seasons. Measurement of cheatgrass and medusahead biomass and seed production on these plots will be completed as part of Study I.

III. Use of Oust© Herbicide to Control Cheatgrass on Burned and Nonburned Sites.

Objectives

To evaluate the effectiveness of Oust© herbicide application rates on weed control and the duration of herbicide effectiveness on burned and nonburned cheatgrass sites.

Materials and Methods

The study is being conducted in an cheatgrass dominated enclosure near Coyote Butte (southwestern two-thirds of T1S, R1E, S10) (Table 3). Three sets of paired plots, each 25 m x 25 m were installed within the enclosure. A 50 m gap was left between the two plots in each pair. One plot in each pair was burned on 30 September 1997 (air temperature 28°C, R.H. 21%, wind SSE at 5 km h^{-1} with gusts 12 to 17 km hr^{-1}). A grid of forty 2 x 3 m subplots was then installed within each of the six plots with 1 m buffer strips between plots. Oust© was applied to separate plots in fall 1997 (29 October) and spring 1998 (1 April) at rates of 0.00, 0.25, 0.50, and 1.00 oz/acre. Herbicide was applied using a hand-operated small-plot precision sprayer. Treatments were randomized within each plot with five replications. Phenological stage of the cheatgrass was noted and litter and soil water were sampled in each plot at the time of each treatment. Additional plots will be burned in summer 1998 and burned and nonburned plots treated with Oust© in fall 1998 and spring 1999. All subplots will be sampled for cheatgrass biomass and viable seed density, weight, and germination for two years following treatment. Data will be analyzed to determine effects of burning and Oust© treatment rates on cheatgrass biomass and seed production.

Acknowledgments

Partial funding for this study was provided by the U.S. Department of the Interior, Bureau of Land Management, Idaho State Office. The U.S. Department of the Interior, Bureau of Land Management and the Idaho State Department of Lands provided the study sites and the U.S. Department of Agriculture, Agricultural Research Service, Northwest Watershed Research Center and Forest Service, Boise National Forest, Lucky Peak Nursery provided weather data.

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Table 1. Description of Oust© application date and rate study sites.

Characteristic	Orchard Research Site	Lucky Peak
Location	Lower Snake River Plain, southwestern Idaho (T1S, R4E, S20)	Boise Front, southwestern Idaho (T3N, R8E, S35/36)
Native vegetation	Artemisia tridentata wyomingensis, Poa sandbergii, Stipa thurberiana	Artemisia tridentata var. womingensis, Purshia tridentata, Pseudoregneria spicata
Disturbance vegetation	Bromus tectorum	Taeniatherum caput-medusae
Elevation (m)	970	975
Slope (°), aspect	0-2, variable	8-15, east-southeast
Mean annual precipitation (mm)	200-300	430
Mean annual frost-free days	140-190	126
Soil	Sandy, mixed, mesic Xeric Torriorthent	Gem Series. Fine, montmorillonitic, mesic, Cumulic Haploxeroll

Table 2. Fall 1996, spring 1997, and fall 1997 Oust© treatment dates and site conditions, Orchard and Lucky Peak.

Location Treatment	Treatment date	Annual grass	Phenological stage	Soil water	Litter
				--%--	-kg/ha-
Orchard					
Fall 1996	6 Nov 1996	Cheatgrass	Germinating	8	2,308.6
Spring 1997	8 April 1997	Cheatgrass	5th-6th leaf	13	1,807.3
Fall 1997	28 Oct 1997	Cheatgrass	Seed	12	7,586.7
Lucky Peak					
Fall 1996	6 Nov 1996	Medusahead	Germinating	15	3,029.2
Spring 1997	8 April 1997	Medusahead	4th-5th leaf	18	2,105.1
Fall 1997	28 Oct 1997	Medusahead	Seed/few germinating	9	4,056.0

Table 3. Description of Coyote Butte study site.

Characteristic	Coyote Butte
Location	Lower Snake River Plain, southwestern Idaho
Native vegetation	Artemisia tridentata var. wyomingensis and Ceratoides lanata mosaic, Poa sandbergii and Stipa thurberiana understory
Disturbance vegetation	Bromus tectorum
Elevation (m)	875
Slope (°), aspect	0-2, south
Mean annual precipitation (mm)	279
Mean annual frost-free days	145
Soil	Fine-silty, mixed mesic Xerollic Aridisol

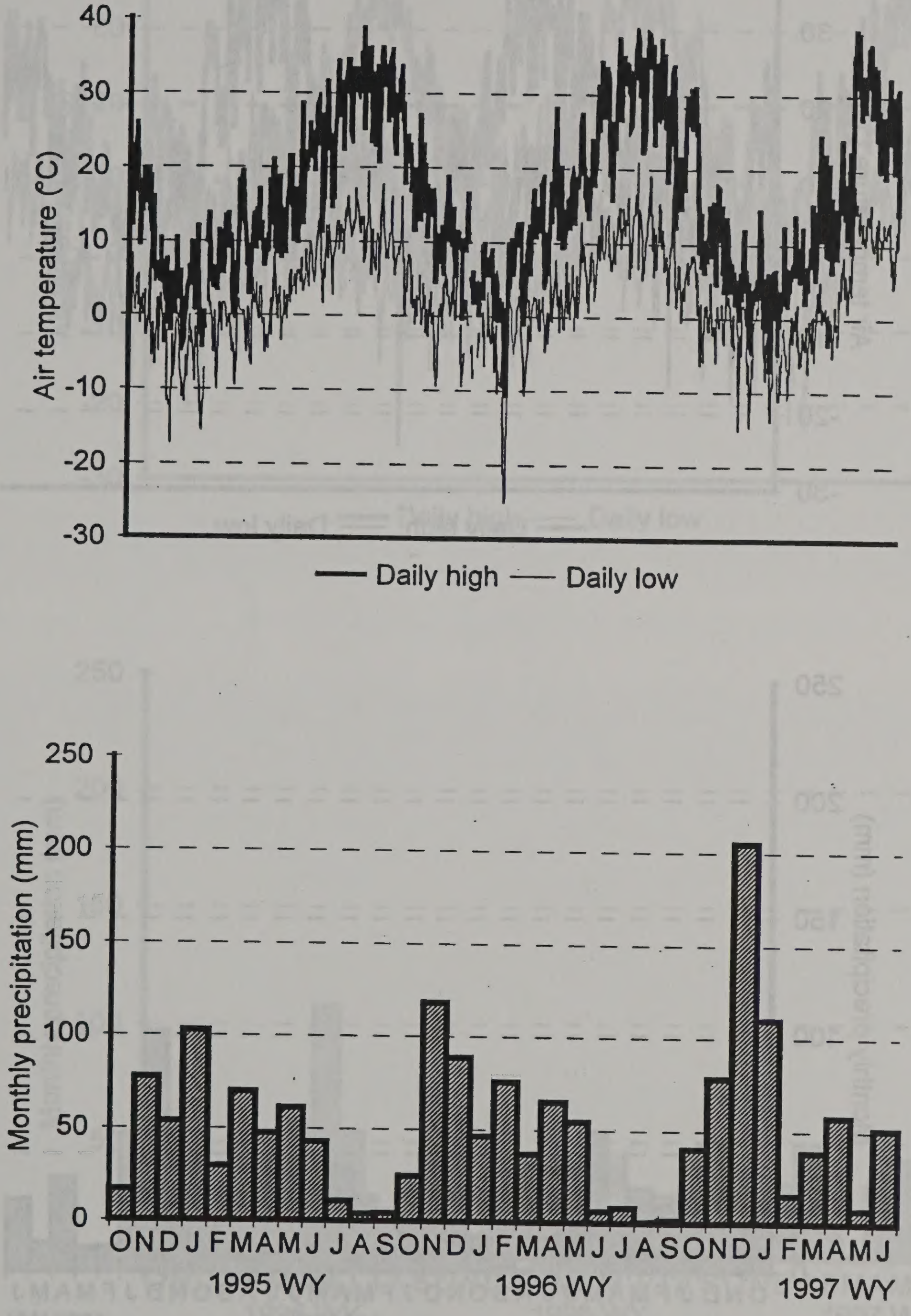

Fig. 1. October 1994 to June 1997 air temperature profile and precipitation, Lucky Peak.

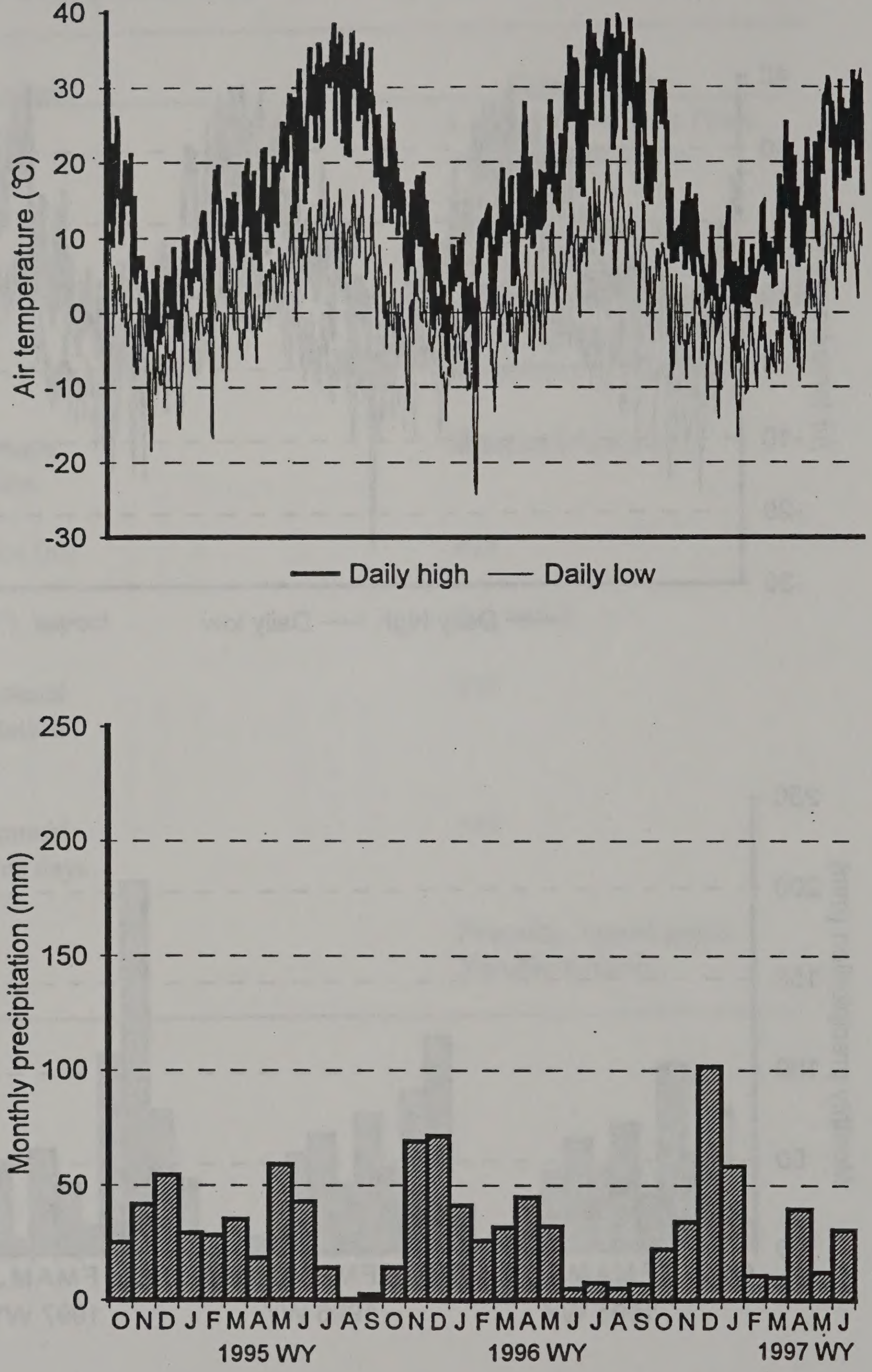

Fig. 2. October 1994 to June 1997 air temperature profile and precipitation, Orchard.

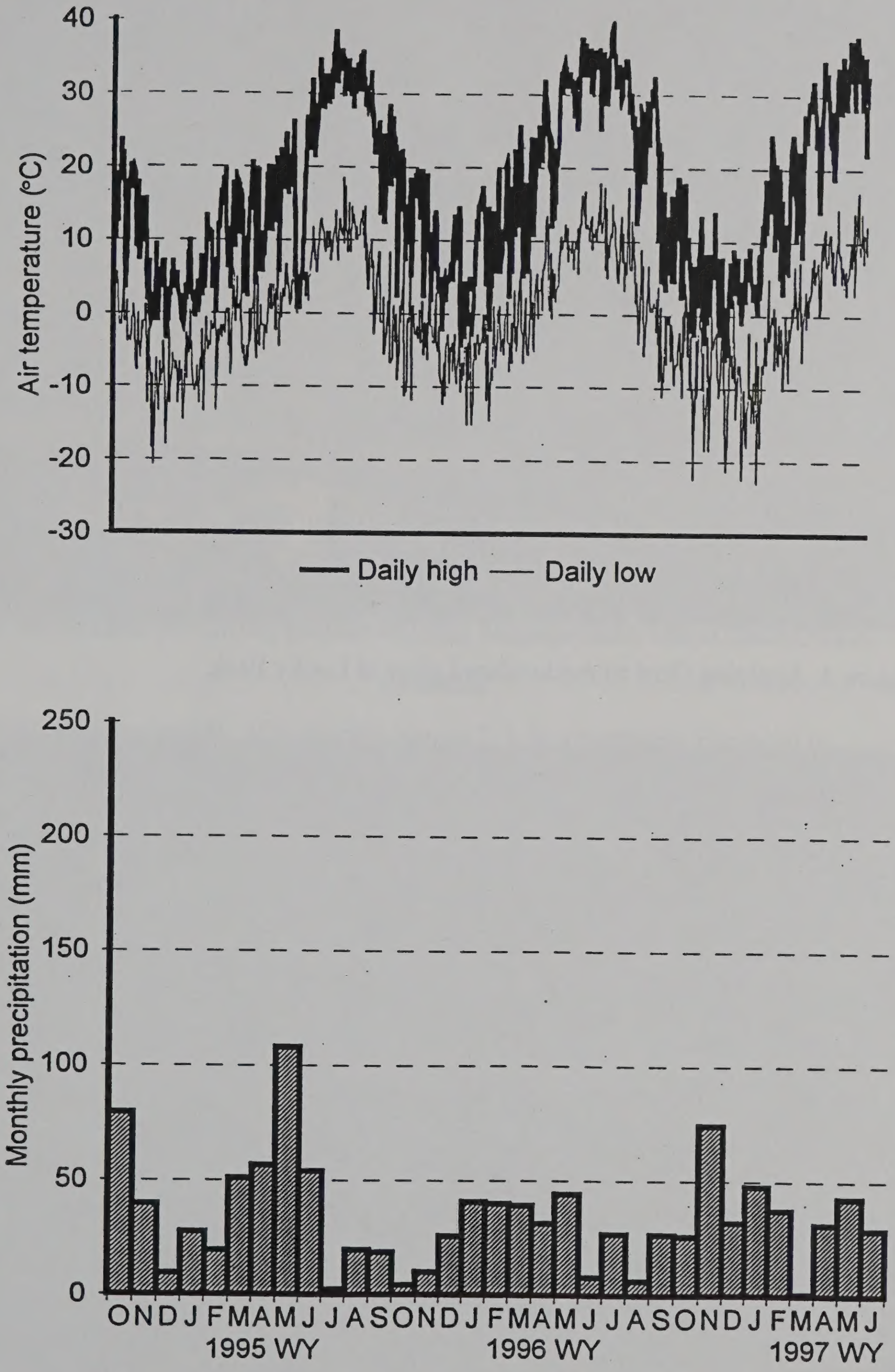

Fig. 3. October 1994 to June 1997 air temperature profile and precipitation, Sorensens Field.

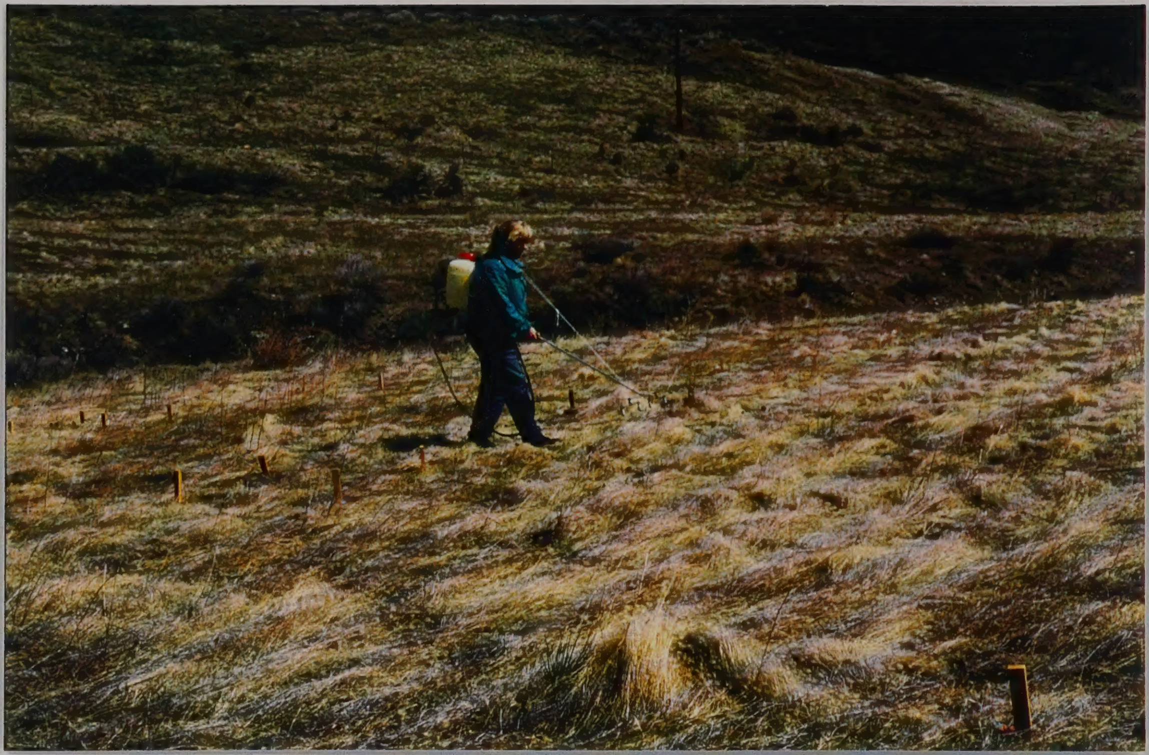

Figure 4. Applying Oust to medusahead plots at Lucky Peak.

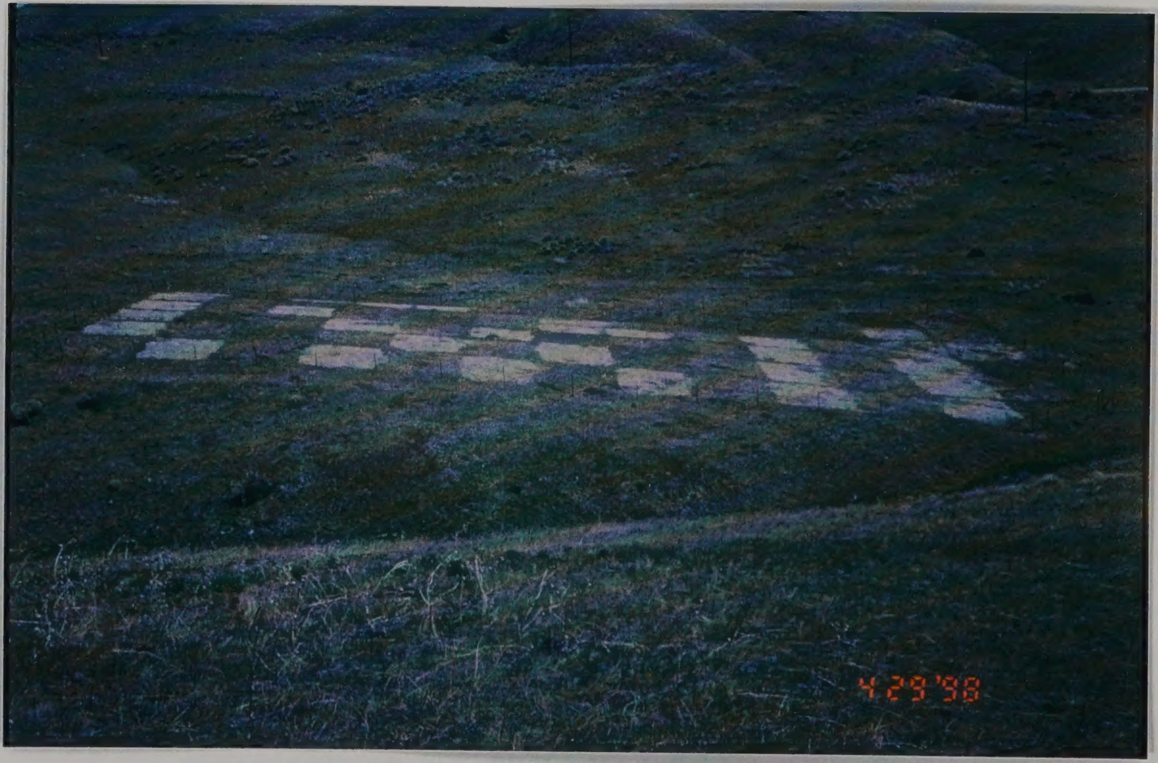

Figure 5. April 1998 view Lucky Peak medusahead plots treated in fall 1996 and spring 1997.

Phenology of Rush Skeletonweed in Southwestern Idaho

J.Liao, V.J. Anderson, S.B. Monsen, and N.L. Shaw

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Problem

Rush skeletonweed, (Chondrilla juncea L.), is a perennial Eurasian or Mediterranean forb (Asteraceae, Cichorieae) introduced to several areas of the world including the United States (Lee 1986, Cullen and Groves 1977, Panetta and Dodd 1987). Small infestations of rush skeletonweed were discovered near Banks, Idaho in 1960 (Schirman and Robocker 1967). The original area of infestation was estimated to be 8 ha. In 1981, rush skeletonweed was estimated to be spreading throughout the Pacific Northwest at a rate of 40,000 ha per year, occupying more than 1.4 million hectares in 12 northern and southwestern Idaho counties (Cheney and others 1981).

Though the plant occupies considerable areas in the Pacific Northwest and California, most studies and control programs were in Australia where the species is considered one of the most serious weeds of cereal cropping (Panetta and Dodd 1984). Here in the United States, rush skeletonweed is considered a serious rangeland weed as it grows in dense monocultures and displaces native plants. Additionally, forage production value of rangeland for domestic livestock and wildlife is reduced (Carroll 1980). The fact that rush skeletonweed is infesting rangeland communities in the United States suggests that this species may have developed adaptive traits to thrive in non-cultivated environments. The goal of this study was to examine the phenological development of this species in southwestern Idaho because a better understanding of its basic biology is essential for the development of integrated control programs effective in controlling local biotypes.

Methods

Populations of rush skeletonweed at two locations in Ada County, southwestern Idaho were selected for study. The Orchard site is at an elevation of 955 m and supports a degraded wyoming big sagebrush (Artemisia tridentata spp. wyomingensis)/mixed bunchgrass community. Precipitation ranges from 20 to 30 cm with most occurring in fall, winter, and early spring. Precipitation may only total 15 to 20 cm in drought years. The soil type is classified as a sandy, mixed, mesic Xeric Torriorthent. This soil type has a deep and excessively drained soil profile. The root zone extends to a depth of 1.5 m or more and the available water capacity is high (Collett 1980). The Shrub Garden site is at an elevation of 1033 m and supports antelope bitterbrush (*Purshia tridentata*) -vasey big sagebrush (*Artemisia tridentata* spp. *vaseyana*) community with a diverse grass-forb understory. Average annual precipitation is 43 cm. The soil is a loamy-skeletal, mixed, mesic Aridic Argixeroll. It is moderately deep and well-drained forming from material that weathered from granite (Collett 1980). Total precipitation for the 1994 and 1995 water years by sites (Orchard and Shrub Garden) is shown in Figure 1.

Phenological development of sixty rush skeletonweed plants, thirty in each of the two study sites, was followed biweekly through the 1994 and 1995 growing seasons. Dates of bolting, branching, first budding, first flowering, and first seeds were recorded biweekly. Floral development from budding through seed formation was followed biweekly for the flowering heads of randomly selected flower clusters at each of four positions (lower, middle, upper, and tip) on each plant. Each head was described as 1=bud stage, 2=flowering stage, and 3=seed stage. Tips were not included in 1995 due to insect damage.

The number of branchlets at each of three primary branch positions (lower, middle, upper) was counted once each season after plants had matured. The number of flowers per head was counted once in 1995 after plants had matured. Precipitation and air temperature were recorded at each location. Data was analyzed by ANOVA and differences mentioned are significant at $p < 0.01$.

Results/Discussion

Precipitation was lower in 1994 compared to 1995 (Figure 1). Plants at both study sites bolted by late April and developed primary branches by mid May in both years. At both sites and in both years, flower bud formation was initiated around mid to late June/early July with first flowering beginning around early July. Earliest seed maturation occurred in mid to late July. Plants continued to form buds, flowers, and set seed at least through September.

Plants at the Orchard site had a higher percentage of heads in the flowering and seed stages sooner than plants at the Shrub Garden site showing an elevational lag response since the Shrub Garden is at a higher elevation (Figure 2). Phenology and flowering occurred earlier in the drier year (1994) than in the wetter year (1995) across both sites. Elevation, precipitation, temperature, and other factors such as aspect or cold air drainage may also contribute to differences in phenological timing.

Although flowering phenology did differ by observation date and between years with plants budding, flowering, and setting seed earlier in the drier year (1994), rush skeletonweed produced flowers and seeds continuously throughout the season at both sites during both years (Figure 3). Because of the extensive root systems that are able to develop in sandy soils, rush skeletonweed at both Orchard and Shrub Garden may have been able to utilize moisture deep in the soil profile, thereby lessening the impact of water stress on flowering and seed production especially during the drier year (1994). Precipitation received during the previous winter may play a more important role in growth and development than the amount of precipitation received during the growing season.

The number of branchlets (number of secondary and/or tertiary branches occurring on primary branches) differed by primary branch position. The lower branch position supported the most branchlets followed by the middle position and then the upper. Lower primary branches developed first, growing to greater lengths and supporting more branchlets. The onset of flowering stages was different only at the tip and not among the other branch positions. Bud formation, flowering, and seed set occurred earliest and first at the apical tips. Though the number of flowering heads per cluster ranged from 1 to as many as 8, the average number of heads in a cluster was 2. In 1994, the number of heads per cluster at the apical tip was greater than that recorded at the other branch positions. The number of heads per cluster did not differ among the lower, middle, and upper branches as counted in 1995.

The plants at the Orchard site had a higher number of heads per cluster than plants at the Shrub Garden. Numbers of heads per cluster generally increased through the season at both sites. The number of flowers per head was similar at both sites and among branch positions with numbers ranging from 9 to 11. Because the numbers of flowers per head were not significantly different between sites or by positions, larger amounts of seed being produced at Orchard may be attributed to greater numbers of flowering heads per cluster and not additional flowers per head.

Rush skeletonweed infestations at both the Orchard and Shrub Garden sites were on sandy or gravelly soils that were deep and well drained. The types of soil in which rush skeletonweed was found at the two study sites were also consistent with those reported in the literature (Panetta and Dodd 1987, Coleman-Harrell et al. 1979, Cuthbertson 1970). These soils allow for extensive root development and the formation and subsequent vegetative regeneration from buds on lateral roots. This type of regeneration is limited in heavier textured soils. In areas at both sites where rush skeletonweed did not occur, the soils were heavier textured with more clay and less sand and gravel. The occurrence of heavier textured soils may be an important limitation to rush skeletonweed spread and establishment.

Management Implications

Rush skeletonweed is an opportunistic plant. It is different from many native species because it begins flowering in mid-summer and continues to produce flowers and seed throughout the growing season, thus avoiding direct competition with many native species. It is able to grow and produce seeds even with an apparent lack of surface soil water during the growing season. Plants are restricted by heavier textured soils and occur only on sandy or gravelly soils. Controls that target flowering and seed production will help reduce the spread of this weed. Controls should be initiated early before flowering begins. Once a population is established, it has great potential to spread and is difficult to control. Rush skeletonweed is adapted to and continues to be a serious weed in many areas of the Pacific Northwest and California. More studies which increase knowledge about the plant and its life history characteristics will be of aid in finding integrated control programs that may effectively halt the spread of this weed and keep existing populations under control.

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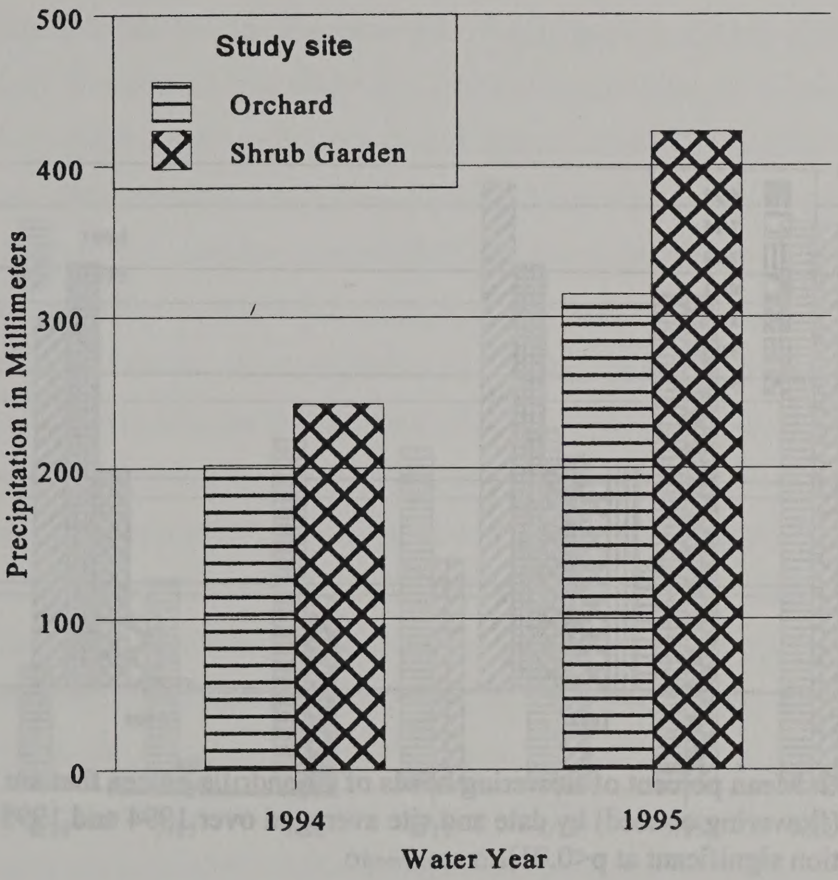

Figure 1. Total precipitation (mm) for the 1994 and 1995 water years at the Orchard and Shrub Garden sites.

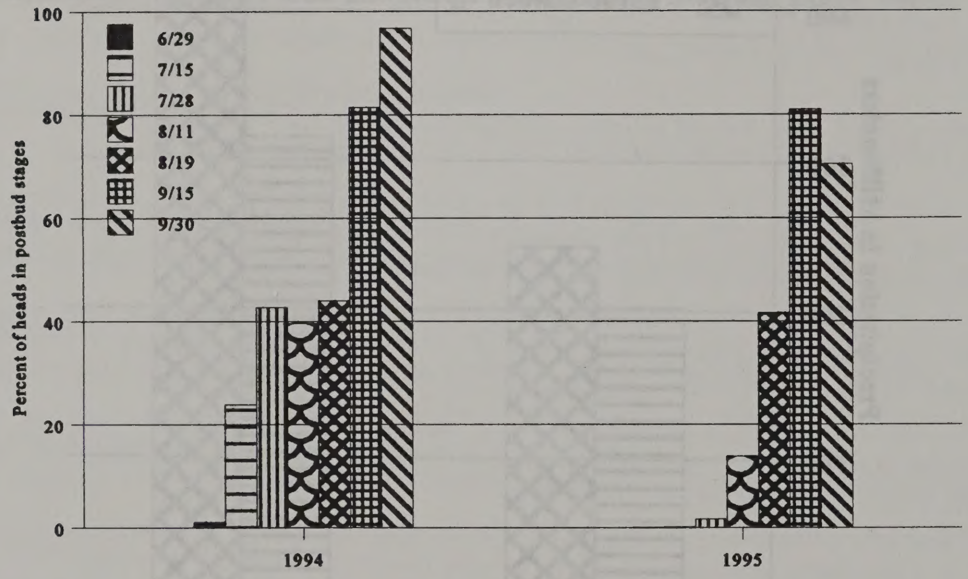

Figure 2. Mean percent of flowering heads of Chondrilla juncea that are in postbud stages (flowering or seed) by date and site averaged over 1994 and 1995 (date x site interaction significant at p<0.01).

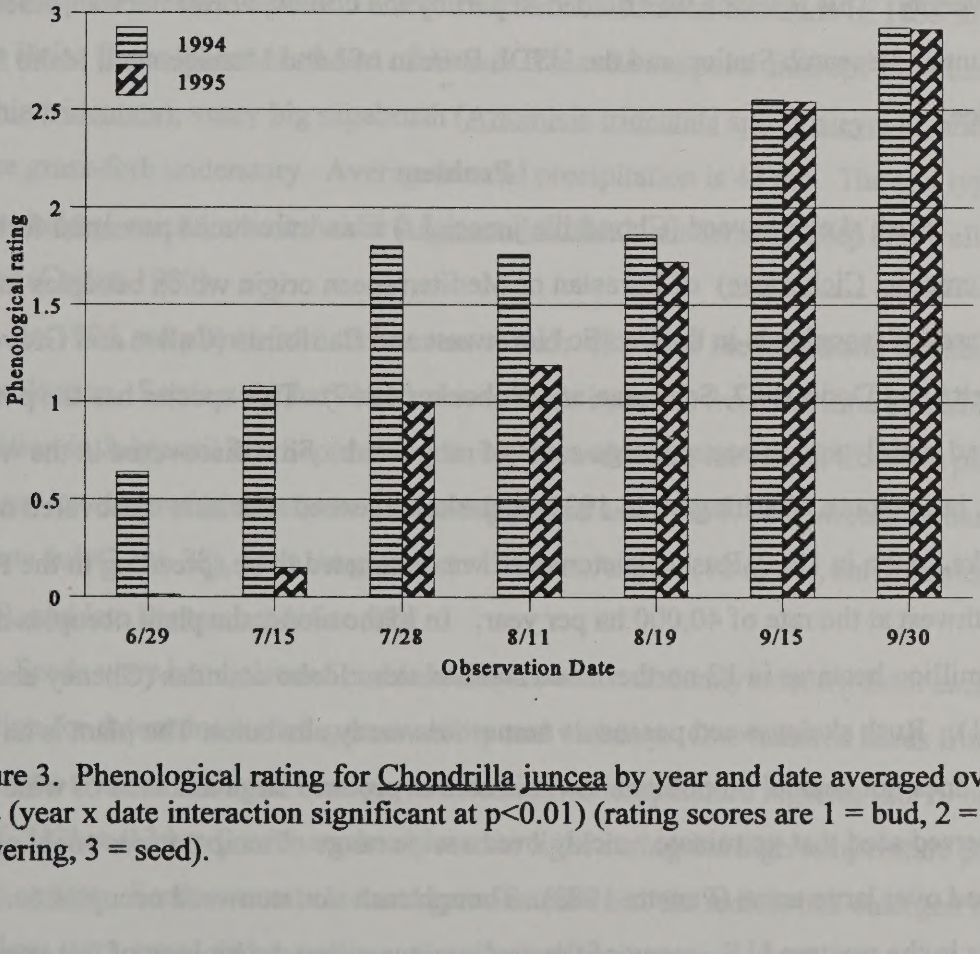

Figure 3. Phenological rating for Chondrilla juncea by year and date averaged over sites (year x date interaction significant at $p<0.01$) (rating scores are 1 = bud, 2 = flowering, 3 = seed).

Seed Germination Study of Rush Skeletonweed in Southwestern Idaho

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Problem

Rush skeletonweed (Chondrilla juncea L.) is an introduced perennial forb (Asteraceae, Cichorieae) of Eurasian or Mediterranean origin which occupies millions of hectares of rangelands in the Pacific Northwest and California (Cullen and Groves 1977, Panetta and Dodd 1987, Schirman and Robocker 1967). This species has the potential to spread rapidly and to occupy large areas of rangeland. First discovered in the western U.S. in Spokane, Washington in 1938, rush skeletonweed was later discovered near Banks, Idaho in 1960. Rush skeletonweed was estimated to be spreading in the Pacific Northwest at the rate of 40,000 ha per year. In Idaho alone, the plant occupies more than 1.4 million hectares in 12 northern and southwestern Idaho counties (Cheney and others 1981). Rush skeletoweed possesses numerous weedy attributes. The plant is an apomict so it does not depend on pollinators. It is able to produce large amounts of wind-dispersed seed that germinate quickly over a wide range of temperatures enabling it to spread over large areas (Panetta 1988). Though rush skeletonweed occupies considerable areas in the western U.S., many of the studies concerning the biology of this species were conducted in Australia where the plant is a serious weed of cereal crops (Panetta and Dodd 1984). The purpose of this study was to learn more about the germination characteristics of biotypes of this species in southwestern Idaho and to see how those results compared with those in the literature. A better understanding of the reproductive potential of this species is essential in finding more effective methods of containment and control.

Methods

Populations of rush skeletonweed at two locations were selected for study. The Orchard site is 32 km southeast of Boise, Ida. at an elevation of 955 m and supports wyoming big sagebrush (Artemisia tridentata spp.wyomingensis)/mixed bunchgrass community. Precipitation ranges from 20 - 30 cm with most occurring in fall, winter, and early spring. Precipitation may only total 15-20 cm in drought years. The soil type is a sandy, mixed, mesic Xeric Torriorthent. It has a deep and excessively drained soil profile (Collett 1980). The Shrub Garden site is located at an elevation of 1033 m and is on the Boise River 27 km northeast of Boise. This site supports antelope bitterbrush (Purshia tridentata), vasey big sagebrush (Artemisia tridentata spp. Vaseyana), and a diverse grass-forb understory. Average annual precipitation is 43 cm. The soil type is a loamy-skeletal, mixed, mesic Aridic Argixeroll which is moderately deep and well-drained (Collett 1980).

In 1994, ten plants from three areas at each site were identified and marked for seed collection. Seeds were harvested at two-week intervals from the time of earliest maturation in July until late September. In 1995, seeds were harvested from the plants in each area on days within the same seven-day period as in 1994. The weeks of harvest were late July(22 to 28), early August (6 to 12), late August (18 to 24), early September (3 to 9), and late September (16 to 22).

Seeds were hand cleaned and subsamples were randomly selected from each collection for determination of germinability and viability. One hundred seeds from each of the three areas at each site were germinated at two temperature regimes (20/10 or 30/20°C [12hrs./12 hrs.]) with seeds exposed to light during the high temperature period of each regime. Seeds were considered germinated when the radicle had emerged and the cotyledons were green and spreading. Germinated seeds were counted at two-day intervals for 14 days. After 14 days, non-germinated seeds were tested for viability. A portion of seeds from 1994 were stored and germinated one year later to examine the effects of dry storage on seed germination characteristics.

Results/Discussion

Total viability of seed lots from both collection sites was lower at the beginning and end of the season in 1995. Viability of seed lots from Orchard increased through early August before declining. Viability of seed lots from the Shrub Garden increased through early September before declining (Figure 1).

Fresh seed from both 1994 and 1995 germinated readily at both temperature regimes though maximum germination percentages were somewhat greater at the lower temperature regime. Rate of germination defined as number of days to 50% germination was generally greater for fresh seeds collected in 1994 compared with 1995 (Liao 1996).

Most fresh seeds collected in 1994 germinated readily, generally reaching germination in excess of 90%. Fresh seeds collected in 1995 were not as germinable as those in 1994 (Figure 2). A small percentage of those fresh seeds that did not germinate were found to be viable (Figure 3). Of the stored seed, a higher percentage of those that failed to germinate, especially those collected late in the season, were still viable. Between 20 and 30% of non-germinated stored seeds remained viable indicating that seeds produced later in the season may acquire secondary dormancy enabling some to persist in the soil seed bank (Figure 3).

Stored seeds did not reach the maximum germination levels as recorded for fresh seeds. Apparently there was some decrease in viability with time. Though not as viable as fresh seeds, stored seeds were germinable and reached maximum germination levels as high as 70% (Figure 4).

Generally, fresh seeds appear to be highly germinable regardless of collection date. Almost all viable seeds germinated immediately. Stored seeds appear to decrease in viability over time.

Management Implications

Rush skeletonweed is a plant that is quite successful in adapting to its surroundings. It possesses many characteristics that enables it to survive and proliferate even under adverse conditions such as high temperatures and limited moisture. Rush skeletonweed has the potential to spread quickly over large areas as a result of the large numbers of viable seeds that are produced and that are capable of germinating rapidly under a wide range of microenvironmental conditions. Some seeds may be acquiring a secondary dormancy enabling them to persist in the soil seed bank. Further work is required to determine whether this occurs in nature since the Australian literature indicate that seeds do not persist in the soil (Panetta 1988). Eradication of rush skeletonweed from most infested areas is difficult because of its many weedy attributes. Control efforts that reduce flowering and seed production will help reduce the spread of this species. Heightened awareness and concern have prompted eradication and control programs. Chemicals such as Picloram and 2,4-D have been found to be effective but impractical due to the high costs of effective chemicals and the large areas of infestation which are of low productivity (Lee 1986, Piper 1983). Many studies now concentrate on biocontrols. Though limited successes are reported, biocontrols have not effectively halted the spread of rush skeletonweed (Lee 1986). Effective control measure are often sought as a goal of research into weed problems, but chances of success are low without a thorough understanding of the specific species biology. Further studies are warranted as a better understanding of rush skeletonweed's reproductive capabilities may provide insight to predicting rates and areas of potential spread and help in the development of much neeeded effective control measures.

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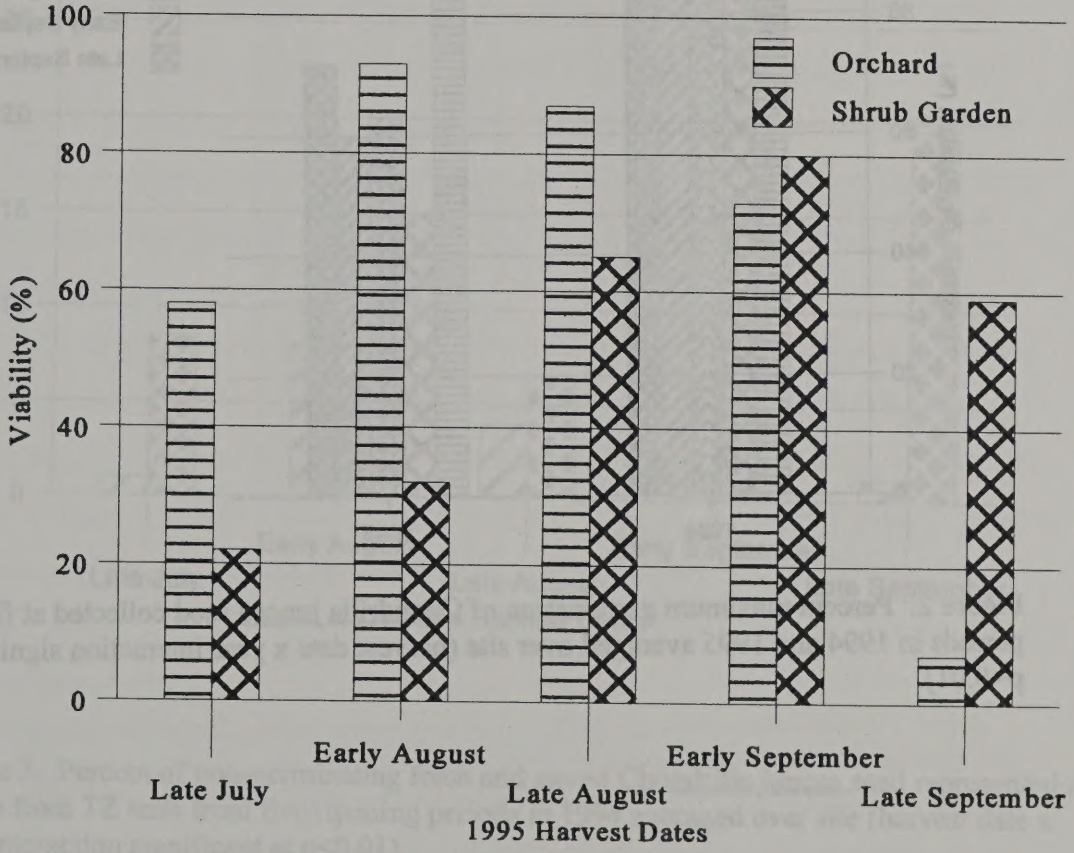

Figure 1. Percent viable seeds of Chondrilla juncea from the Orchard and Shrub Garden sites collected at five different ripening periods in 1995 (date x site interaction significant at $p<0.05$).

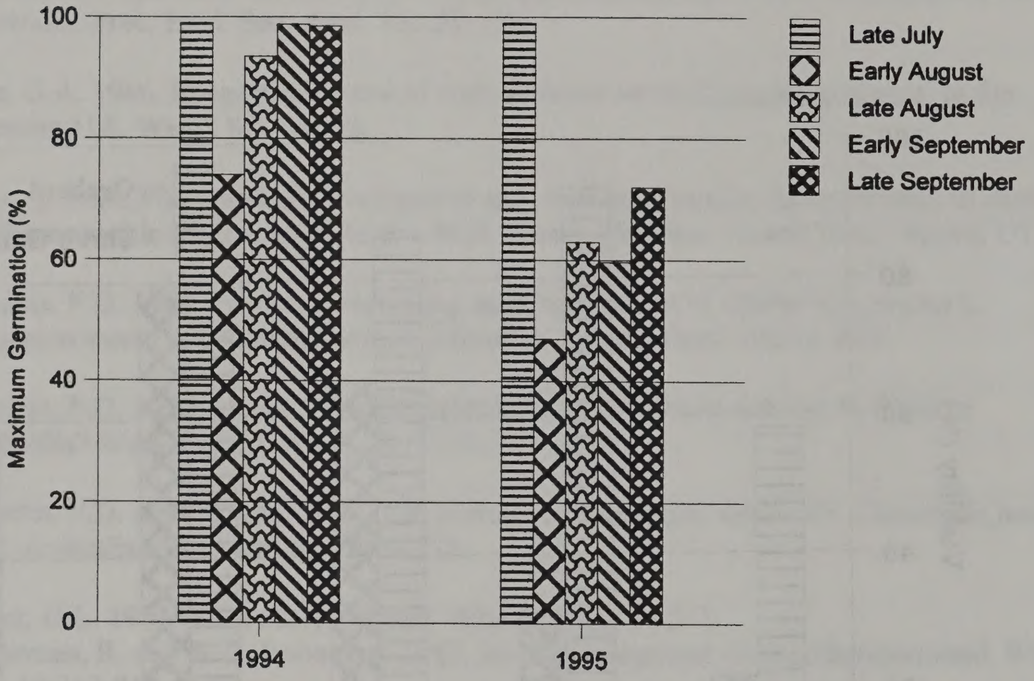

Figure 2. Percent maximum germination of Chondrilla juncea seed collected at five ripening periods in 1994 and 1995 averaged over site (harvest date x year interaction significant at $p<0.01$).

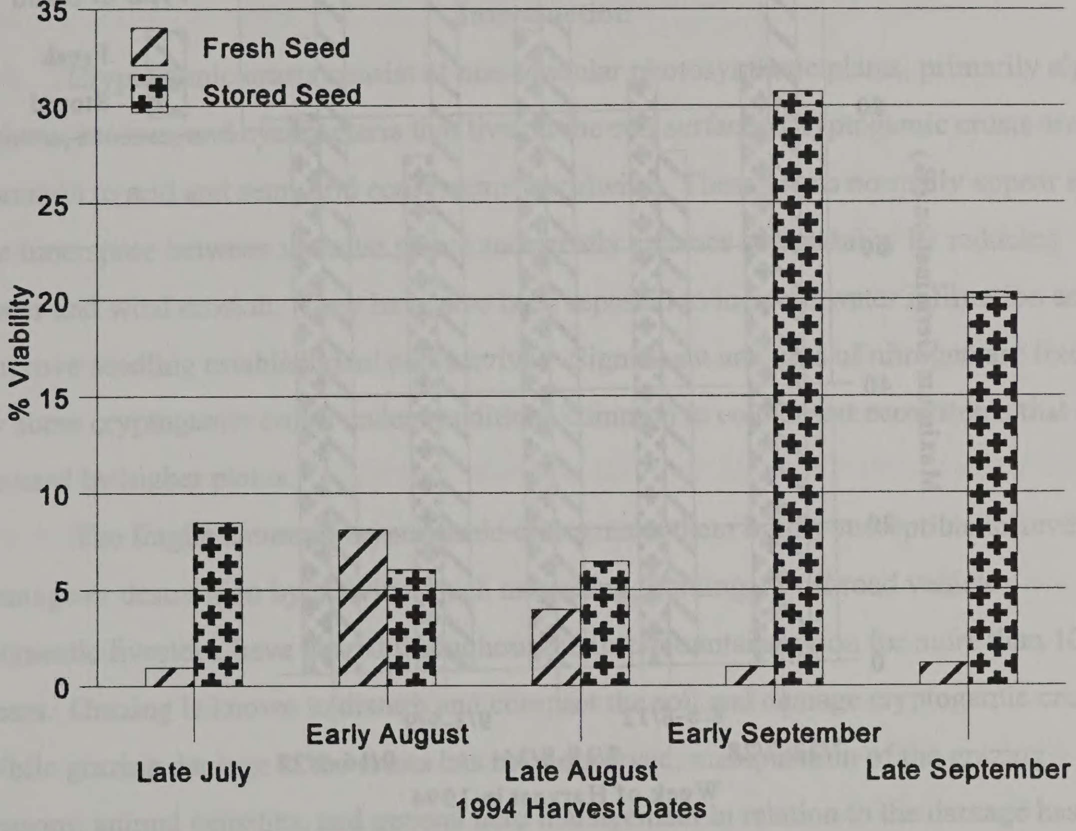

Figure 3. Percent of non-germinating fresh and stored Chondrilla juncea seed represented as viable from TZ tests from five ripening periods in 1994 averaged over site (harvest date x year interaction significant at $p<0.01$).

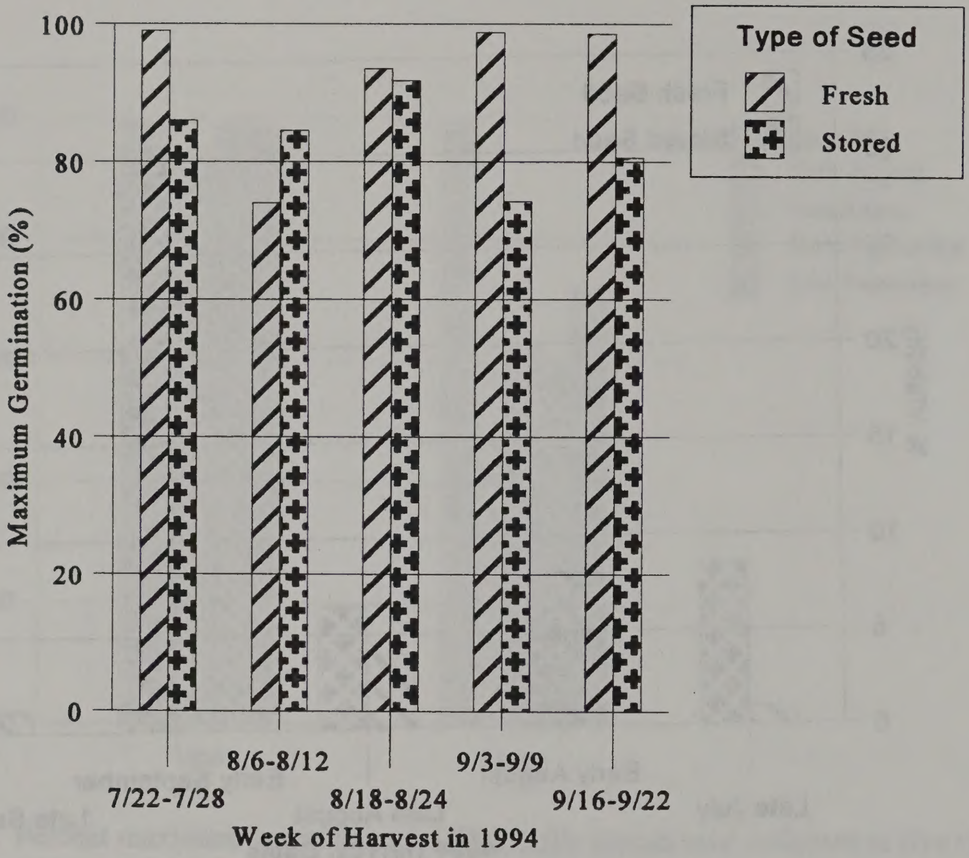

Figure 4. Percent maximum germination of fresh and stored Chondrilla juncea seed collected at five ripening periods in 1994 averaged over site (harvest date x year interaction significant at $p<0.01$).

Seasonal Grazing Impact on Cryptogamic Crusts in a Cold Desert System

Kelly L. Memmott, Stephen B. Monsen, and Val Jo Anderson

Introduction

Cryptogamic crusts consist of non-vascular photosynthetic plants, primarily algae, lichens, mosses, and cyanbacteria that live on the soil surface. Cryptogamic crusts are common to arid and semi-arid ecosystems worldwide. These crusts normally appear in the innerspace between vascular plants and greatly enhance soil stability by reducing water and wind erosion. They have also been reported to increase water infiltration and improve seedling establishment and survival. Significant amounts of nitrogen are fixed by some cryptogamic crusts under conditions common in cold desert ecosystems that can be used by higher plants..

The fragile nature of cryptogamic crusts make them highly susceptible to severe damage or destruction by activities such as grazing, burning, or off road vehicles. Domestic livestock have grazed throughout the Intermountain region for more than 100 years. Grazing is known to disturb and compact the soil and damage cryptogamic crusts. While grazing damage to the crusts has been observed, manipulation of the grazing seasons, animal densities, and general herd management in relation to the damage has not been widely studied.

Study Objectives

The purpose of this study was to determine if cattle grazing at different seasons would have different impacts on established cryptogamic crusts. The study was also designed to evaluate the effects of seasonal cattle grazing on the recovery of crusts in a cold desert ecosystem in southwestern Idaho.

The study area was located approximately 14.4-km. North of Malta, Idaho adjacent to the Brigham Young University Skaggs Research Ranch.

Methods

The response of cryptogamic soil crusts to four grazing and two tillage treatments were examined in a factorial arrangement in a randomized complete block design with four replications. The grazing treatments consisted of spring, summer, winter, and an ungrazed control, while the tillage treatments included 1-m. Tilled strips with 2.5-m untilled strips. Shrub seedlings were transplanted at 1.5-m intervals into the tilled strips.

The 20-ha study site was prepared in the fall of 1985 by aerial spraying 2,4-d. A broadleaf selective herbicide, to remove all existing shrub species. After the tilling treatment in 1986 shrubs were transplanted into rows at 1.5-m intervals, of single species per parcel. The shrubs selected were: big sagebrush (Artemesia tridendata), prostrate kochia (Kochia prostrata), big rubber rabbitbrush (Chrysothamnus nauseosus,) fourwing saltbush (Atriplex canescens), and winterfat (Ceratoides lanata).

The perimeter was fenced and then subdivided into four sections representing the four treatments. The shrubs were allowed to establish for two years before grazing trials were conducted. The pastures were grazed according to season (spring, summer, winter, and control or no grazing) until there was an fifty percent approximate reduction in the grass understory. Grazing trials were performed for the period of two years. After a one year rest a ten point pin frame was used to determine cover types on the soil surface. Within each pasture 60 stratified random placements of the pin frame were made in the tilled and untilled portions of the pasture. Hits were recorded by five cover classes: litter, bare ground, vascular plant (by species), moss, and lichen. Percent cover was calculated by dividing the number of hits on a cover type by the number of points sampled and multiplying by 100. Statistical analysis was done to determine response differences and mean separations.

Results and Discussion

Cryptogamic cover was dominated by mosses ranging from 97% in the winter grazed plot to 87% in the control. Total cryptogamic cover was affected by grazing period and tillage showing significant differences in the winter grazed and control pastures as opposed to the spring and summer grazed pastures. Cattle hoof action on softened and sometimes wet soils in spring and summer was sufficient to disturb the soil surface and reduce cryptogamic cover by nearly 50%. Breaking the soil surface exposed soil particles and induced erosion by wind and water. Frozen soils in the winter combined with snow cover provided a barrier against such disturbance. Bare ground was highest on the summer grazed plots (39.2%), followed by spring (36.3%), winter (31.7%). and control (20.2%).

Management Implications

Previous studies document the negative impacts of ungulate grazing on cryptogamic crusts. The majority of these studies were completed in desert ecosystems that do not sustain frozen soils for long periods of time. Those that do, however, do not detail stocking rates and specific timing of grazing. The traditional winter grazing season goes well beyond the time when the frost leaves the soil surface.

This study has demonstrated that cattle grazing can adversely affect cryptogamic crusts at certain times of the year, it also shows that taking advantage of frozen soils in the winter allows managers to graze cattle at proper stocking rates without damage to the soil crusts. This is beneficial to areas in the Intermountain West that are susceptible to wind and water erosion where continued grazing in the spring and summer may jeopardize the long-term stability of the environment.

Relevant Literature

Brotherson, J. D., S. R. Rushforth and J. R. Johansen. 1983. Effects of long-term grazing on cryptogam crust cover in Navajo National Monument, Ariz. J. Range Manage. 36:579-581.

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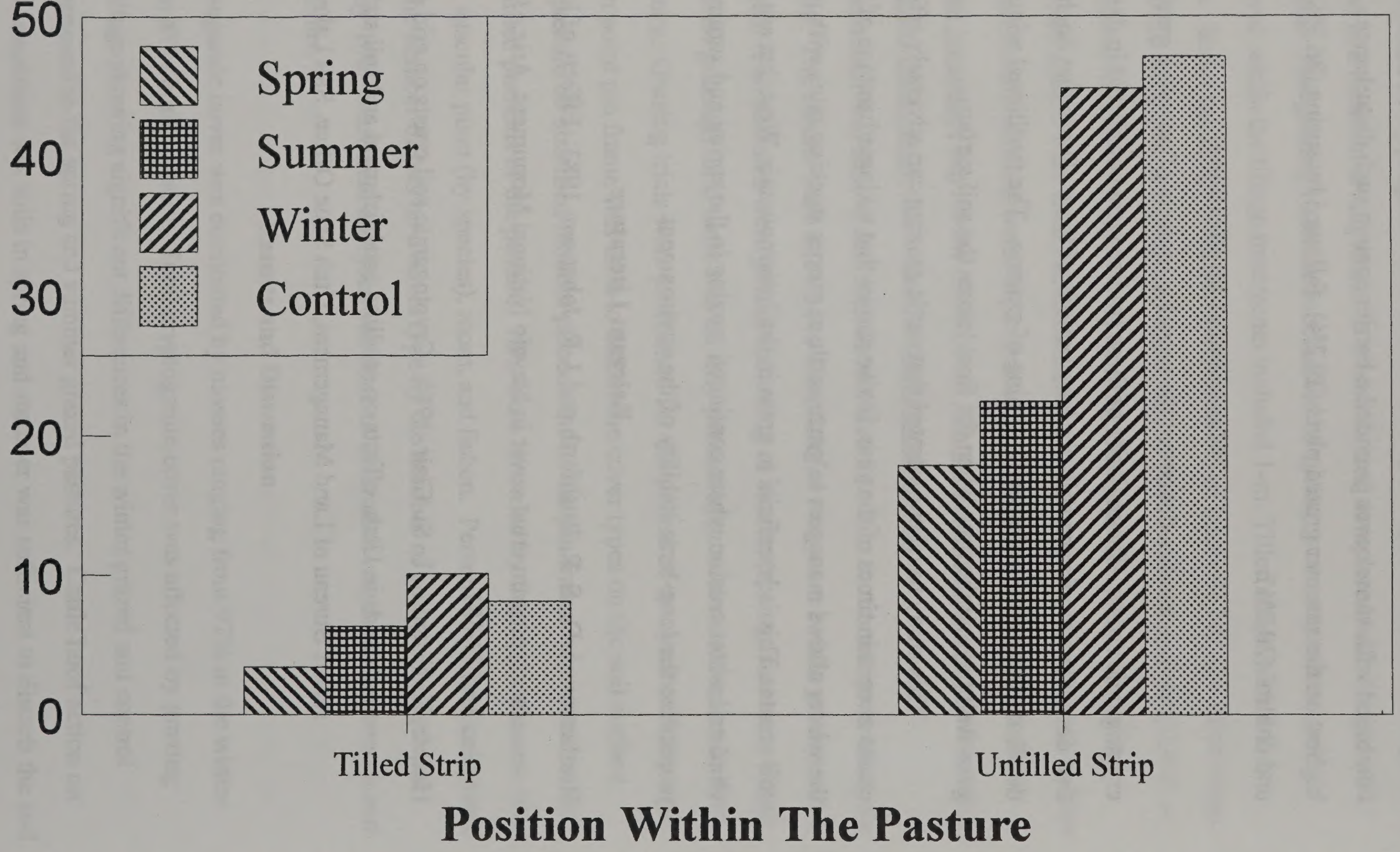
Total Cryptogam Cover (%)

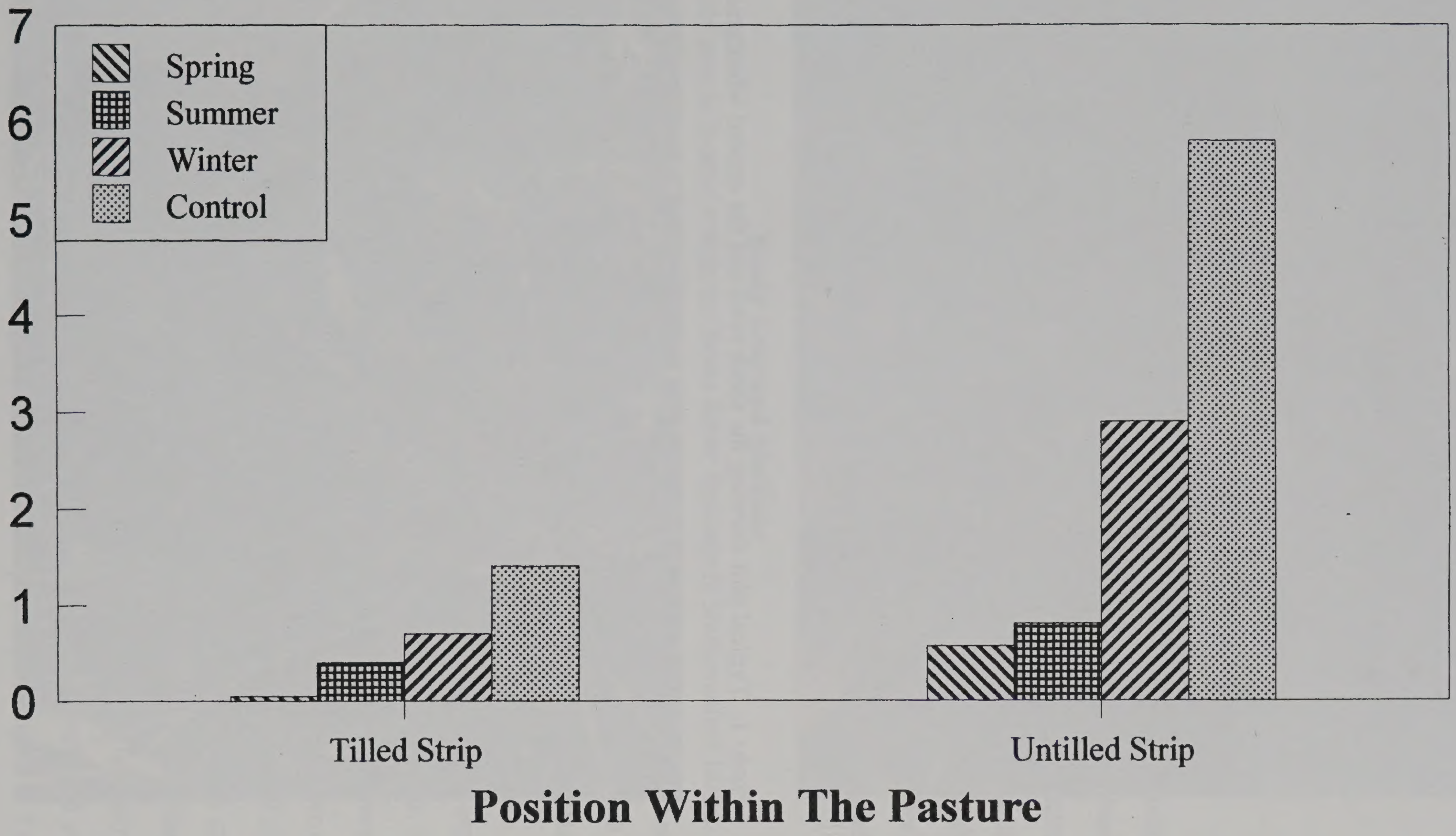
Figure 1.



Total cryptogam cover shows a significant difference in winter and control plots than spring and summer plots

Total Lichen Cover

Figure 2.



Lichen cover is greater in the control plots followed by winter grazed plots and summer and spring grazed plots

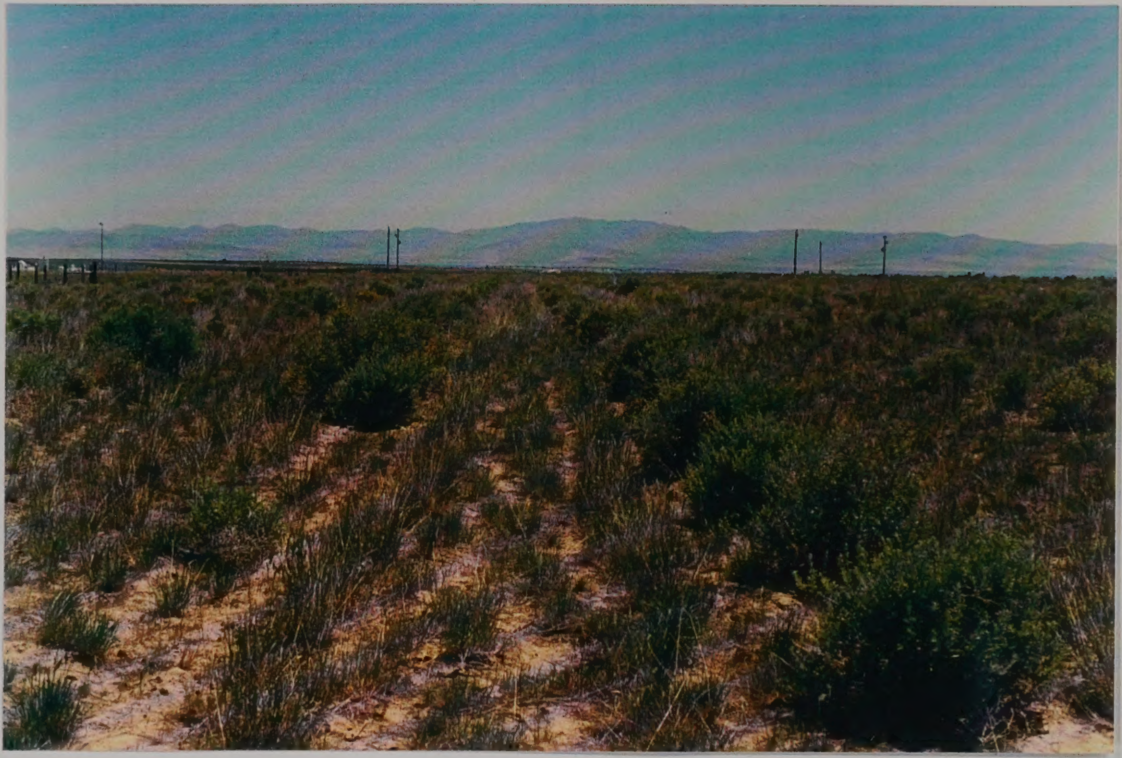


Photo 1. Typical plot showing the shrub rows and the crested wheatgrass innerspace.

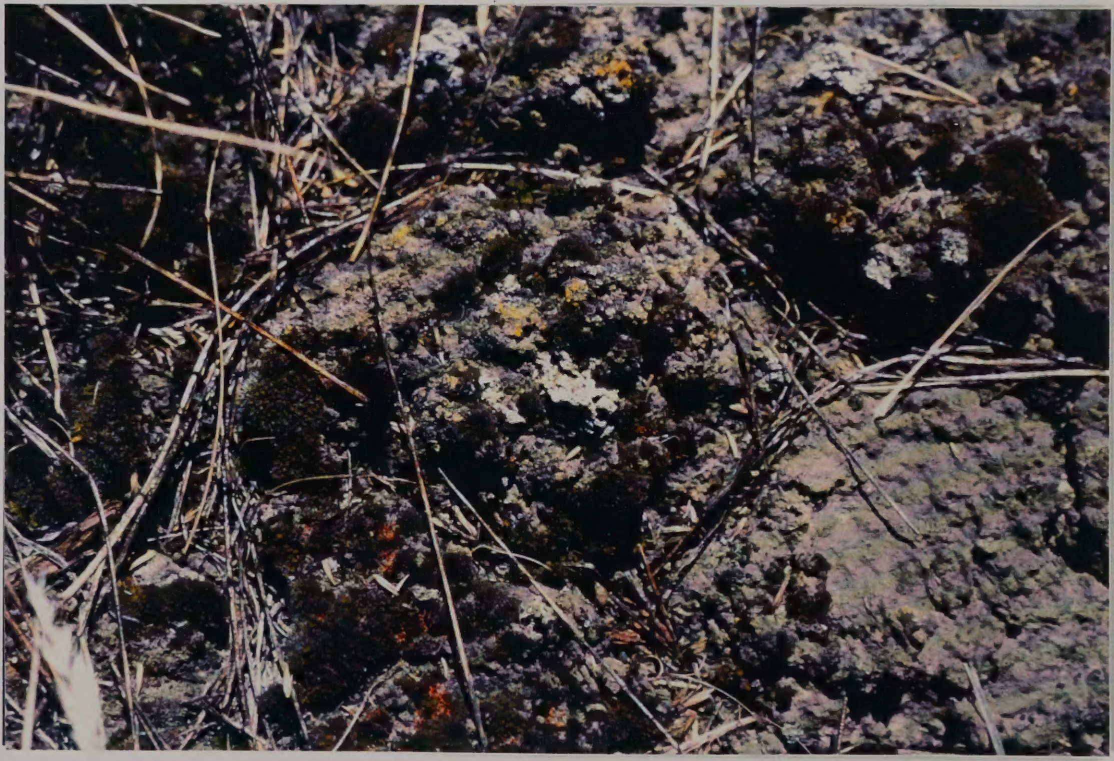


Photo 2. A typical sample of cryptogamic crusts of the study area; note the mosses, lichens and litter.

Persistence of Cheatgrass Amid Bunchgrass Shrub Steppe Communities

Stephen B. Monsen and Nancy L. Shaw

Introduction

Severe overgrazing by livestock in the late 1800's and early 1900's disrupted many bunchgrass/shrub steppe communities in the Intermountain region. The condition of these sites was further impacted by invasion of annual weeds, particularly cheatgrass (Bromus tectorum). Regulating grazing to enhance reestablishment of native species and displacement of annual weeds is a primary concern. Understanding factors affecting rates and patterns of secondary succession is critical in management of weed infested sites. Documentation of vegetation changes in response to grazing systems and climatic conditions requires maintenance of field study sites over an extended period of time.

Study Area and Methods

The study area is located within the Boise River drainage in southwestern Idaho, a highly dissected area with deep, v-shaped valleys, and residual granitic soils (Renner 1936). Annual precipitation ranges from about 40 to 53 cm with 70% falling in winter and spring (Voth 1979). Four exclosures, Wood Creek (1,188 m elevation), Lower Bellmare (1,401 m), Upper Bellmare (1,554 m), and Elk Creek (1,280 m) were constructed between 1927 and 1931 on sites representative of habitat types from dry mountain big sagebrush (Artemisia tridentata ssp. vaseyana) and bluebunch wheatgrass (Psuedoregneria spicata) to more mesic mountain big sagebrush, mountain snowberry (Symphoricarpos oreophilus) and bluebunch wheatgrass. Slopes vary from about 37 to 67% and aspects generally from south to southeast. All exclosure sites were subjected to heavy grazing by sheep, cattle, and horses from late 1800's to the 1920's when reductions were imposed. All plant communities had been seriously disrupted by early grazing. Allotments were converted to cattle use by the mid-1960's and modifications of rest-rotation grazing systems instituted. Species composition and foliar cover were estimated ocularly on ten 5 X 5 m plots in both the grazed and protected areas at each exclosure site in each of 8 years from 1930 to 1977. Plots were subdivided and vegetation measured separately in strips 1 X 5 m in size. Percent cover provided by perennials was determined by measuring the diameter of each plant and cover of annuals was carefully estimated.

Results and Discussion

Cheatgrass was present inside and outside all four exclosures in 1931 (Table 1), but declined from 1933 to 1937 following several drought years. A similar pattern of cheatgrass loss was reported by Voth (1979). Presence of cheatgrass was erratic in both grazed and protected areas from 1940 to 1977 (Table 1), with its cover never exceeding 6%.

Perennial grass cover was initially low in grazed and protected areas at all sites and showed little or no improvement through 1940 (Table 1). It did not diminish appreciably during the period of drought. Cover provided by perennial grasses in protected areas at all exclosures generally increased between 1955 and 1977. The effect was most pronounced at the more mesic Elk Creek site where perennial cover exceeded 10% in 1977. Perennial grass cover showed only slight, if any improvement in grazed areas over this period and did not exceed 4.5% at any site. Sanders and Voth (1983) also reported slow improvement of perennial grasses, but reported little difference between protected and grazed locations. Total ground cover of all species increased during the study period, with the most significant changes also recorded between 1955 and 1977 (Table 2).

Bluebunch wheatgrass was the most prevalent perennial grass at all study sites and increased in ground cover more rapidly than any other species (data not shown). Only small amounts of sandburg bluegrass (Poa secunda) and june grass (Koeleria cristata) were recorded at any location during the study period.

Recovery of native perennial bunchgrasses has occurred slowly with only moderate improvement in protected areas after 47 years. The rate of recovery was likely slowed by extreme deterioration of the watershed early in the century, leaving unstable, eroded soils and limited seed sources of native plant species. Drought conditions continuing after grazing reductions and exclosure construction may have further impeded recovery. Cheatgrass has persisted over time, even with protection from livestock grazing in two exclosures. This species is capable of proliferating following fire or other disturbances and competing with establishment of perennial grass seedlings.

Management Implication

Recovery of native communities within the bunchgrass/shrub steppe type, through protection from grazing, can be a slow process. Displacement of cheatgrass and reestablishment of native species is dependent upon the degree of degradation prior to sites being protected from grazing. Sites lacking an assembly of native perennials will recovery slowly. More arid sites also recover slower than more moist sites. Generally, sites occupied by wyoming big sagebrush Artemisia tridentata spp. wyomingensis) recover slowly. Lack of a sufficient seed source is critical to community restoration. Although species such as sandburg bluegrass and bottlebrush squirreltail (Sitanion hystrix) are considered as pioneer plants capable of colonizing these communities, few plants appeared during the 47 year period. No plants were initially present, limiting subsequent recovery.

Minor increases in plant cover of perennial species can diminish the presence of cheatgrass. Reducing livestock grazing of more moist sites can result in a significant decline of annual weeds. Cheatgrass can be expected to persist at reduced levels on more arid sites until native perennials have recovered more completely.

Grazing management is an important practice in determining the recovery of cheatgrass infested sites. Through protection, native recovery can be expected, but rates are dependent upon the presence of existing perennials, and climatic conditions. Areas should not be allowed to deteriorate resulting in the loss of important species.

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Table 1. Percent ground cover of cheatgrass and perennial grasses in protected and grazed areas at 4 exclosures as estimated in each of 8 years, 1930 to 1977.

Vegetation Treatment	Year							
Exclosure	1930	1931	1933	1934	1937	1940	1955	1977
Cheatgrass				%				
Protected								
Wood Creek	--	6.0	0.6	0.0	0.0	0.0	0.4	1.0
Lower Bellmare	4.9	1.8	0.1	0.0	0.0	0.9	0.2	3.1
Upper Bellmare	0.7	0.5	0.0	0.0	0.0	0.5	0.2	0.0
Elk Creek	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Mean	1.6	2.2	1.2	0.0	0.0	0.4	0.2	1.0
S.D.[1]	0.7	1.0	0.2	--	--	0.3	0.2	1.2
Grazed								
Wood Creek	--	4.9	0.5	0.2	0.0	0.0	0.6	0.0
Lower Bellmare	0.8	2.4	0.0	0.0	0.0	5.1	0.2	1.7
Upper Bellmare	1.2	1.9	0.7	0.0	0.0	5.9	0.5	0.2
Elk Creek	0.3	2.1	1.6	0.0	0.0	0.0	0.8	0.0
Mean	0.6	2.8	0.7	0.0	0.0	2.8	0.5	0.5
S.D.	0.3	2.5	1.0	--	--	2.7	0.8	0.7
Perennial Grasses								
Protected								
Wood Creek	--	0.0	0.2	0.1	0.2	0.4	2.4	3.8
Lower Bellmare	1.7	0.7	1.1	1.0	1.3	0.6	4.8	6.2
Upper Bellmare	1.0	3.1	4.4	3.2	2.1	4.1	2.3	4.8
Elk Creek	2.8	1.9	2.9	1.6	1.4	3.1	3.5	11.9
Mean	1.4	1.4	2.2	1.5	1.2	2.0	3.2	6.7
S.D.	0.8	0.5	0.8	0.6	0.5	0.6	1.3	1.8
Grazed								
Wood Creek	--	0.0	0.0	0.0	0.0	0.8	1.5	2.6
Lower Bellmare	1.1	2.0	0.4	0.3	0.3	0.5	1.7	4.2
Upper Bellmare	2.2	0.7	1.4	1.0	1.0	1.4	2.2	4.2
Elk Creek	0.7	1.5	2.2	1.3	1.7	2.1	2.0	0.7
Mean	1.0	1.0	1.0	0.6	0.8	1.2	1.8	2.9
S.D.	0.8	0.9	0.6	0.3	0.4	0.7	0.9	1.8

[1] Standard Deviation

Table 2. Total vegetative cover in protected and grazed sites at 4 exclosures in each of 8 years, 1930 to 1977.

Exclosure	1930	1931	1933	1934	1937	1940	1955	1977
	%							
Wood Creek								
Protected	--	7.1	3.0	1.1	1.5	1.5	4.8	16.0
S. D.[1]	--	3.0	1.5	0.6	0.6	0.5	4.0	6.9
Grazed	--	7.1	2.2	1.3	0.9	4.3	3.2	12.8
S. D.	--	4.1	1.1	0.8	0.5	1.6	0.6	6.5
Lower Bellmare								
Protected	11.3	5.2	5.9	8.6	6.4	6.8	10.7	16.5
S. D.	4.9	2.8	7.9	9.9	9.5	4.7	4.0	7.8
Grazed	10.9	8.2	3.6	2.8	3.5	11.7	15.8	23.2
S. D.	7.8	4.0	2.4	2.1	2.9	3.9	4.8	7.3
Upper Bellmare								
Protected	13.7	5.4	8.7	5.0	3.9	7.6	12.4	21.0
S. D.	4.1	1.2	3.6	1.9	1.3	1.3	3.3	6.2
Grazed	10.1	6.3	9.2	3.3	3.8	11.0	11.4	22.4
S. D.	1.6	0.3	4.9	1.1	0.3	3.6	2.2	4.2
Elk Creek								
Protected	13.8	8.3	11.1	5.6	5.2	8.1	10.5	43.0
S. D.	1.6	2.7	1.6	0.9	0.3	1.9	2.1	25.0
Grazed	5.1	6.9	10.6	3.5	3.9	7.6	10.6	22.7
S. D.	5.8	3.6	6.5	2.0	2.4	2.5	2.3	9.1

[1] Standard Deviation

Interseeding Fourwing Saltbush with Crested Wheatgrass for Winter Livestock Grazing

Stephen B. Monsen and Nancy L. Shaw

Introduction

Range and wildlife plantings frequently include the use of shrubs to improve species diversity, increase herbage production, extend periods of grazing, and provide more stable plant communities. Woody plants dominate many semiarid communities within the Intermountain region, and provide important habitat to wildlife and domestic animals. Extensive shrublands have been disrupted by grazing coupled with the invasion of annual weeds, and a subsequent increase in fire frequency. Many native shrub/bunchgrass rangelands have been converted to annual grasses reducing forage, wildlife habitat, and watershed resources. Unless disturbances are revegetated with perennial species, annual weeds reappear increasing the frequency of fires. To date rehabilitation measures used to restore many sites have relied upon the use of crested wheatgrass (Agropyron cristatum). Many extensive crested wheatgrass plantings dominate semiarid shrublands, and fail to provide wildlife habitat and winter herbage. Seeding shrubs directly with perennial grasses following wildfires is being conducted with some success. Seedling establishment is dependent upon weed control and availability of seasonal moisture. Interseeding shrubs into existing stands of crested wheatgrass is desirable in many areas to increase diversity and provide winter herbage to wildlife and domestic animals. Fourwing saltbush (Atriplex canescens) has been seeded in the salt desert communities it once occupied prior to disturbance. It has also been seeded within the wyoming big sagebrush (Artemisia tridentata spp. wyomingensis) type to provide winter habitat where extensive stands of shrubs have been lost.

Most native shrubs species are slower growing and more difficult to establish by direct seeding than more competitive herbs. Shrub and herbs usually can not be seeded together, but must be seeded in separate rows or spots to reduce competition. This study was established to investigate the feasibility of interseeding fourwing saltbush with crested wheatgrass to provide winter habitat. Shrub longevity, adaptability, and recruitment were evaluated.

Methods

In August 1971, a large wildfire burned approximately 9,700 hectares of wyoming big sagebrush (Artemisia tridentata spp. wyomingensis) and cheatgrass (Bromus tectorum) rangelands in the Sugar Creek drainage Owyhee County, Idaho in August 1971. Following burning, 3,036 hectares were interseeded to crested wheatgrass and fourwing saltbush. Grass was seeded using rangeland drill which planted twelve rows in a strip 9.2 meters wide. Fourwing saltbush was simultaneously planted in an adjacent row using the "Hansen Seed Dribbler" (Larsen 1980) which was mounted on the track of the caterpillar used to pull the grass drill. Grass was seeded at a rate of 6.7 kilograms pure live seed (PLS)/ hectare, and fourwing saltbush was seeded at a rate of 0.42 kg (PLS)/ha. Beginning in 1973, approximately 830 cattle were allowed to annually graze from 1 November to 1 March.

In 1976, permanent transacts were established in 7 separate areas within the planting to inventory shrub numbers, size, annual production, percent use and flowering. Additional use transacts were established in areas located at 0.40, 0.80, 1.20, and 1.60 kilometers from the nearest watering center. Grass yields and cover were recorded at the principal study locations using 200 randomly located meter plots. Data was analyzed using analysis variance procedures, alpha= 0.05.

Results and Discussion

The mean number of shrubs recorded in 1978 for all study sites was 227 plants/ hectare, table 1. All bushes had attained mature statue within 4 years following planting. Shrub density varied among sites from 108 plants/ha to 355 plants/ha. Seeding rate employed was not sufficient to provide a full stand of uniformly spaced shrubs, yet based on the amount of seed planted shrub density is similar to numbers reported for plantings at other locations (Wood et al 1982). Sites are capable of supporting over 1,000 shrubs/ha, and in some locations numbers approached this figure. Shrub numbers declined in both 1978 and 1980 due to severe winter mortality from abnormally low temperatures recorded between December 1978 and February 1979. During this period temperatures dropped below -25° C on five different dates. In addition, annual precipitation in 1979 was only 14.1 cm, a significant departure from normal. Shrub mortality was quite similar among all study sites for both years. Shrub numbers declined about 10 percent in 1978 to 207 plants/ha, and an additional 5 percent in 1980 resulting in 195 plants/ha. No recruitment of shrub seedlings were recorded at any date from 1976 to present. Approximately 40 percent die back was recorded among all bushes for all sites in 1978. Seed planted at the Sugar Creek location was obtained from native stands at a warmer location in southern Utah, which likely contributed to its demise. Van Epps (1975) reported high winter mortality of fourwing saltbush ecotypes collected from warm climates and planted at much cooler locations in central Utah.

Shrubs produced a substantial amount of herbage in 1978, but yields declined significantly in 1979 and 1980 for all sites (table 1). Yields decreased as plants were damaged from mid-winter frosts in 1978-79, and as a result of low precipitation received in 1979. Plants were so seriously damaged in 1978-79 that bushes did not recover for at least two growing seasons. Mean annual production in 1978 for individual bushes at all sites was 1,873 grams of dry herbage. Mean yields per bush ranged among the 7 sites from 2,709 to 1,346 grams. Yields are similar to those reported by (Petersen et al 1987) of different ecotypes growing in western Texas. Yields were significantly differed among sites particularly in 1978 and 1979. Yields of individual bushes declined to 658 g/plant in 1978 and 362 g/plant in 1980. Although precipitation received in 1980 was nearly double the amount received in 1979, bushes were not able to fully recover.

Male and female bushes produced similar amounts of herbage in 1978, although the heaviest bushes were seed-bearing plants. McArthur et al. (1992) reported no significant difference in size of male and female bushes of plantings established in western Colorado. Female bushes provided significantly more herbage than male bushes in 1979, but yields were reversed in 1980.

In 1778, shrubs provided 427 kg/ha of dry forage compared to 707 kg/ha of grass. These figures are about half the amounts reported by (Rumbaugh et al. 1982) for mixed shrub grass seedings in central Utah where shrubs were planted at closer spacings. Shrub yields declined for all sites in 1979 and 1980, although grass production remained consistent. Petersen et al. (1987) recognized ecotypic variations in fourwing saltbush influenced survival and growth and recommended selection and development of site adapted sources to ensure maximum production during periods of stress.

Prior to 1978, grasses had invaded and occupied the understory beneath the seeded shrubs. Grass production was not suppressed by the presence of the overstory shrubs.

Rumbaugh et al. (1982) reported fourwing saltbush plants improved grass yields when plants were grown together in mixed plantings.

Conclusions

Seeding fourwing saltbush and crested wheatgrass in separate rows is a suitable method of establishing both species. Fourwing saltbush should be seeded at rates of 1.8-2.0 kg/ha of PLS. Endemic ecotypes of fourwing saltbush should be planted to assure germ plasm is site adapted. Fourwing saltbush plants can provide sufficient winter forage for grazing animals without decreasing understory grass yields. Cattle will remove about fifty percent of current years growth of the shrubs. Shrub yields, flowering, and seed production can be expected to fluctuate due to climatic conditions.

Planting fourwing saltbush with perennial grasses or seeding this shrub into existing stands of grass is possible if grass competition is removed. This practice can restore diversity and improve winter habitat to extensive areas where shrub/herb diversity has been lost.

Fourwing saltbush is not recommended for seeding wyoming big sagebrush communities. It can furnish high quality herbage in a relative short time, and improve critical winter habitat to game animals. However, plants are usually not sufficiently adapted to persist for extended periods. Natural recruitment of new seedlings does not occur when seeded with crested wheatgrass. Existing stands can be expected to naturally die out.

Management Implications

Attempting to improve shrub diversity of disturbed salt desert wyoming big sagebrush communities can be accomplished by seeding fourwing saltbush with perennial grasses. Interseeding fourwing saltbush into sites currently occupied by crested wheatgrass is also feasible. The practice can enhance winter herbage production and habitat for wildlife where extensive disturbances have occurred. Fourwing saltbush ecotypes are site adapted, and seeding local ecotypes is necessary. Seeding fourwing as a permanent species on wyoming big sagebrush sites not originally supporting this species is not advised.

Natural recruitment of fourwing saltbush is restricted by crested wheatgrass, and shrubs cannot be expected to persist beyond the life of the seeded generation. Interseeding fourwing saltbush with crested wheatgrass may be a short-term solution providing wildlife habitat and seasonal herbage to livestock, but the practice should not be advised as a restoration measure.

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Van Epps, G.A. 1975. Winter injury to fourwing saltbush. J. Range Manage. 28:157-159.

Table 1. Number of fourwing saltbush plants and mean yields per bush for 7 study sites for 3 different years (1978-1980).

Study	No. Plants			Yields[1]		
Site	1978	1979	1980	1978	1979	1980
	-----Plants/ha-----			-----g/bush-----		
A	214	79	72	1,352c	706b	276bc
B	144	130	132	1,854bc	771ab	267bc
2	127	118	122	1,346c	384c	296bc
3	43	26	15	2,709a	832ab	272bc
4	125	102	95	1,957bc	382c	207bc
5	50	49	43	2,031b	1,055a	487a
5A	71	74	69	2,683a	905ab	416ab
Means	110	82	78			

[1] Means within a column having the same letter are not significantly different at 0.05 level.

Future Research

Priorities for future research include the following:

1. **Species Selection and Release.**

   Objective: Develop adapted native plant species required to seed fire breaks and restore disturbed plant communities dominated by cheatgrass and other annual weeds.

Status and proposed future work: Growth chamber, laboratory, greenhouse, and field studies have been conducted over the last 10 years to identify accessions of forage kochia (Kochia prostrata [L.] Schrader), yarrow (Achillea millefolium L.), and small burnet (Sanguisorba minor Scop.) valuable for use as firebreaks in greenstrips. Additional studies have led to the selection of Thurber needlegrass (Stipa thurberiana Piper), Sandberg bluegrass (Poa secunda Presl), and bluebunch wheatgrass (Pseudoregneria spicata [Pursh] Love) accessions suitable for revegatation efforts on the lower Snake River Plain. Release of all six accessions requires production of foundation and later generation seed to supply potential seed growers, publication of available data, completion of the formal release process for each accession, and cooperation with state Crop Improvement Associations to promote seed production of the releases by private growers.

2. **Seed Production Studies.**

   Objective: Complete seed production studies of the six potential releases listed above in order to provide detailed seed production guides to prospective private growers.

Status and proposed future work: Studies of plant adaptation and ecology, germination and seedling establishment, plant morphological and phenological development, and cultural practices required to maximize seed production morphological and phenological development are being conducted at Utah and Idaho Field sites by the Shrub Sciences Laboratory and in cooperation with the Utah Division of Wildlife Resources and the U.S. Department of Agriculture, Aberdeen Plant Materials Center and Upper Colorado Environmental Plant Center. Completion of these studies, publication of the data, and preparation of seeding guides for each release are essential to insure and expand their viability as commercial seed varieties.

3. Continue Testing Flammability of Greenstripping Species.

Objective: To select fire resistant plant materials and planting designs for use in greenstrip seedings.

Status and proposed future work: Experimental procedures were developed and tested for burning across dry and highly flammable annual vegetation into blocks or strips of seeded plant selections currently used or under test for possible use in greenstip seedings. Evaluation of greenstrip effectiveness was accomplished by measuring changes in rate of fire spread, temperatures, flame length, and total distance traveled by the fire. Further studies will examine the effectiveness of additional plant materials and planting designs utilizing multiple species. Publications resulting from this work will aid in the design of more efficient and reliable greenstrips for specific site conditions.

4. Expand Oust Herbicide Studies.

Objective: Expand current studies to examine the impact of the herbicide on selected native plant species, native plant communities, and soil biota.

Status and proposed future work: Current Oust herbicide studies were designed to (1) examine the effectiveness of seasonal application dates and herbicide rates on cheatgrass (Bromus tectorum L.) and medusahead (Taeniatherum caput-medusae [L.] Nevski) dominated sites and on recently burned sites; (2) determine the duration of soil activity of the herbicide; (3) evaluate the effects of residual herbicide on germination and establishment of common revegatation species seeded in fall, one growing season after fall or spring application. Although the herbicide normally does not kill established plants, some species are more sensitive and easily damaged than other. Impacts of the herbicide on rangeland soil biota are largely unknown. Although the herbicide will be used largely in areas dominated by cheatgrass, remnant components of native above ground and below ground communities often exist as mosaics within cheatgrass dominated areas. Residual native populations often cannot be avoided by operational ground or aerial application equipment. Therefore, it is essential that seasonal sensitivity of major as well as rare species be assessed to aid managers in planning herbicide applications to reduce competition of annuals on sites scheduled for later seedings. An additional proposed use of the herbicide is to treat degraded rangelands with adequate residual understory to permit natural recovery without seeding if competition is reduced. Again, guidelines regarding the sensitivity of native species would be essential for planning such projects.

5. Install Community Restoration Projects.

Objective: Install community restoration projects in several major plant community types to provide demonstration areas and facilitate studies of plant establishment and interactions in mixed species plantings.

Status and Proposed Future Work

Establishment and persistence of artificially established native communities requires (1) careful selection of species with balanced competitive abilities or species capable of partitioning resources in space and time; (2) development of appropriate seeding technology for each species; (3) control of weedy competition; (4) development of seeding techniques, seeding rates, and spatial arrangements for establishing and maintaining each mixture utilizing a knowledge of species interactions at various life stages. Most planting efforts in the intermountain have involved only a few native species. Increasing emphasis on restoring entire communities will require increased knowledge of plant life histories and interactions.

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